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THE NATURAL SCIENCES AND MATHEMATICS

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The Natural Sciences and Mathematics

Reviews the literature for the three-year period since the issuance of Vol. XVIII, No. 4, October 1948. Earlier research related to this topic was reviewed in Vol. XV, No. 4, October 1945.

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FOREWORD

This is another in a series of numbers of the Review devoted to summarization of research in the fields of mathematics and science. In general the method of procedure of the committee preparing this number has been the same as that of its predecessors. It will be noted that three chapters are devoted to science and three to mathematics. Not quite the same division of labor was followed in the setting up of the chapters covering the two subjects. In general, workers in the field of the teaching of science tend to be interested in that subject as taught both in the elementary school and in the high school. Accordingly, each of the first three chapters deals with selected aspects of the teaching of science, without any attempt to divide the discussion in ways which correspond to typical administrative divisions of schools.

Most workers in the field of the teaching of mathematics, however, confine their interest either to the teaching of arithmetic in the elementary school or to the teaching of high-school mathematics. In accordance with the prevalence of these interests, it seemed best to divide the last three chapters along these lines. Parenthetically, it may be noted that the mathematics program in schools tends to be an eight-four program, regardless of the manner in which the school system is organized administratively. Administratively, and perhaps pedagogically, the mathematics program in what are usually considered the junior high-school grades, is pretty chaotic. But in any case, research concerned with the program in Grades VII and VIII is incorporated in the chapter on arithmetic, while that concerned with the teaching of algebra or general mathematics in the ninth grade is referred to in the chapter on high-school mathematics.

No effort will be made here to discern trends, or to compare or contrast the research reported here with that reported in previous issues of the Review. Mention should be made, however, of one significant development. About 16 years ago workers in the field of arithmetic teaching were given a new phrase, "the meaning theory." Like many another but less worthy bit of pedagogical phraseology, it achieved considerable currency. Gradually it became apparent that here was a concept of great significance, which held high promise of making an important contribution to the teaching of the subject. It is gratifying to note that the present report indicates that research workers are attacking vigorously the problems of refining the theory, particularizing it, and using it to bring new insights to teachers and children.

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CHAPTER I

The Science Curriculum

ELSA MARIE MEDER

IN REVIEWING the literature of the past three years dealing with curriculum research in science, certain general impressions are gained which are encouraging and even inspiring. They are these: (a) The areas of most activity are those with the longest tradition. For example, science was taught in the colleges before it found its way into high schools, elementary schools, and early childhood education; yet there appears to be currently more rethinking of the function of science in general education at the college level than at any precollege level. (b) There is recognition that education is primarily a matter of learning rather than of teaching: at all levels instructors are participating with their students in the adventure of learning, and thus demonstrating that learning is exciting. (c) There is a pervasive concern with human values: if science education is good, it is good in terms of its effects on the learners. Consequently, there is a willingness to reexamine the content of courses in terms of its value for students. (d) There is little evidence of a tendency to exalt science unduly; rather there are indications of a healthy humility, a willingness to face the failures of science as well as to glorify its successes, and a recognition of the partnership in scientific research of creative imagination and the step-by-step process of verification.

Aims of Science Instruction

The objectives of science teaching have frequently been grouped in four categories, as was done recently by Anderson (2): attainment of factual information; understanding of broad principles of science and their application to specific situations; understanding and use of the scientific method; and acquisition of scientific attitudes. Emphasis on facts for the sake of factual knowledge has been steadily declining in general education courses at all levels; emphasis on objectives in the other three categories has been as steadily increasing. A fifth category, development of a philosophy of living in accord with the extent and nature of scientific knowledge (which has been included in statements of objectives in the past), has received less attention in recent research reports of workers in science education, despite the growing general concern for moral and spiritual values in American education.

During the three-year period under review, there has been a decrease in the number of research studies directed toward the identification of principles important in the various science subjectmatter areas, perhaps because of the quantity and quality of earlier work toward this end (cited in the October issues of the REVIEW OF EDUCATIONAL RESEARCH in 1945

and 1948). Some of this hitherto unpublished work has recently become generally available (31, 34). Research on the identification of science principles for use in elementary education has been reported as in progress (47).

Meanwhile, there has been a noticeable increase in the number of publications concerned with the development of understanding of scientific method and concomitantly of scientific attitudes. Most of these have been discussions rather than reports of research. The very acceptance of "scientific method" as an aim susceptible to definition and attack has been questioned and, of course, defended, as in an interchange between Kruglak (24) and Blake (5). Rogers (51) pointed out that this aim is dual in nature, involving both training in scientific investigation and showing what science is like. The latter he deemed one of the most important goals of science in general education, and one which may afford an opportunity for encouraging habits of critical thinking and their transfer to nonscience activities.

According to George (17), it is necessary to recognize that all standard treatments of the nature of scientific method in all languages are based on philosophy, and that most of them are written by persons who have done no scientific research. Nagel (38) attempted to clarify the concept of scientific method of analyzing its content and value; he held that scientific method is the subjectmatter of the logic of inquiry and that it can be explored profitably only in conjunction with the concrete materials of the sciences. Friedenberg (16) reported the definition by the staff of the college general biological sciences course in the University of Chicago of a major objective which had not previously been defined as such: the development of insight into the underlying structure of the biological sciences. Attainment of such insight would be evidenced by ability to distinguish structural artifacts from basic data and would be of value in helping students relate biological information to other aspects of their experience. A committee of the National Association for Research in Science Teaching has been attempting to identify and describe aspects of problem-solving ability; two reports of its deliberations have been published (41, 42).

Research pertinent to discussions of scientific method was carried out by Lampkin (26), who prepared a detailed formulation of the scientific method of inquiry, primarily from a study of philosophical works. In a carefully controlled investigation, he found that competent judges, whether trained as science teachers or in philosophy, were unable to agree on what aspect of scientific inquiry was being described in various passages of science textbooks, or even whether or not there was any consideration at all of scientific inquiry. (See Chapter II.)

The Search for Valid Bases of Objectives

In a recently published summary and interpretation of the long-term experiment of the Bureau of Education Research in Science, previously

reported only in part, Laton and Powers (27) described ways in which objectives have been sought and found by secondary-school teachers in studies of the communities in which they teach, of the young people with whom they deal, and of the problems which adults face in contemporary life. In a progess report of an extensive experimental general-education project in Battle Creek, Michigan, Evans and others (14) described how a cooperative research committee of high-school teachers and consultants developed objectives concerned with problem-solving, values and value patterns, and understandings, attitudes, and skills basic to effective personal living and group participation.

While agreeing that objectives may legitimately be sought in study of the young people being taught, Nedelsky (43) maintained that in higher education, at least, the objectives of a course should be stated explicitly and in detail in terms of what the students should be like after completing the course. One method of arriving at such objectives is to state the most general objective first, even if it seems platitudinous; then, after clarifying it, to identify particular contributions the course should make toward that general objective. A second method is to start with the particular content of the subject and identify the generalized abilities to which it can contribute. Nedelsky stated that both methods should be used in formulating objectives. He pointed out that in most courses the content dimension is perfectly clear to the instructor, but that it is not clear what the student completing the course should be able to do with the content; hence objectives should be stated in terms of behavior. He proposed five criteria for objectives: communicability, importance, teachability, testability, and comprehensiveness.

The Science Curriculum in Elementary Schools

The curriculum in science at all levels is being adapted to the changing aims of instruction. Craig (11) pointed out that the rethinking of the purposes of science in childhood education is bringing about a realization that science in the elementary school must be apropriate to children—their ideas of themselves and of their world; their interest in discovering facts for their own purposes; their natural applications of critical thinking, however fragmentary these seem to adults; their development and growth in resourceful and intelligent behavior. Such science is not the content of high-school biology, chemistry, and physics brought down to an elementary-school level, nor is it the rigid application of sequential steps in the scientific problem-solving method as reported by laboratory research workers; rather it is the exploration of events in the environment and the development of explanations to them, and as such it utilizes the natural drives of children. But only a beginning has been made in this respect. Lammers (25) found that, while 74 of 100 elementary-school teachers interviewed said they were free to utilize science materials as they chose, 50 of the 100 relied solely on correlative and incidental learnings for instruction in science. The primary need of these 100 teach-

ers was identified as the development of insights concerning the purpose and place of science in elementary education: 33 teachers believed its aim to be interpretation of the environment, while to 23 it was the satisfying of curiosity; only 17 seemed to have any perception of its importance in the development of behavior patterns. In reporting the progress of an extensive program of integrated research in the problems of teaching science and health in elementary school, Otto (47) stated that most courses of study in elementary science and health had been found to be conglomerate in nature and to give little evidence of conscious or thoughtful consideration of objectives. He suggested that, if a sound curriculum in science is to be developed for the first six grades, four approaches to the formulation of objectives must be harmonized: the nature-study approach; an approach from the general purposes of education; consideration and analysis of the principles of science; and study of the common activities or areas of living. He indicated that efforts to achieve such harmonization were being made.

The Status of the Secondary-School Science Curriculum

A study of science teaching in Grades VII thru XII was made during the first half of the school year 1947-48 under the auspices of the United States Office of Education and reported by Johnson (22). Data concerning science offerings and enrolments were obtained from a stratified random sample consisting of 715 of the approximately 24,000 public high schools in the United States. In Grades VII and VIII, general science was almost the only science offering; in Grade IX, it was the standard course, altho it was sometimes alternated and sometimes replaced with biology. Sixty-two percent of the pupils in the seventh grade, 78 percent of the eighth-graders, and 66 percent of the ninth-graders were enrolled in general science; 75 percent of all Grade X pupils were enrolled in biology. In other words, more than two-thirds of the children in these four grades were receiving instruction in science. The picture was different for Grades XI and XII, where the standard offerings were chemistry and physics, respectively. About 20 percent of all students in Grades XI and XII were taking chemistry; about 13 percent of them were taking physics.

In this connection Johnson presented a tabulation of the percent of pupils in the last four high-school grades who were enrolled in science courses in various years in which statistics were collected. The percent in ninth-grade general science was found not to have changed materially since 1922, the first year for which data were available, hovering around 18 percent. The percent enrolled in biology rose steadily from about 7 percent in 1915 when it was first reported to the 20 percent found in the 1947 survey. The percent of pupils in chemistry remained remarkably constant; it was 10 percent in 1890 and almost 9 percent in 1947, having fluctuated between the 1890 high point and lows of about 7 percent in 1905 and 1928. The high point of physics enrolment was 1895, when almost 23 percent of the young people in high school studied physics.

Since then, the decline has been continuous; the percent enrolment was 5.5 in 1947.

In close agreement with the findings of the Office of Education study were results reported by Sanford (52) of a survey of science enrolments in Illinois high schools, made as part of the Illinois Secondary School Curriculum Program. In 1947-48, the enrolments in general science, biology, chemistry, and physics were, respectively, 19 percent, 19 percent, 7 percent, and 6 percent of the Illinois high-school population. The similarity of the results of the Illinois survey to the data obtained by the Office of Education in the same year adds interest to another aspect of the Illinois inquiry—the science preparation of students entering the University of Illinois as freshmen in September 1948. Of these students, 80 percent had had general science, 63 percent biology, 62 percent chemistry, and 70 percent physics. Evidently the study of chemistry and physics in Illinois high schools was virtually limited to college-bound youth. A study made at San Francisco State College in 1947, while dealing with a population not strictly comparable to that at the University of Illinois, nevertheless is similarly suggestive. Morse (37) reported a survey of the high-school science courses taken by 506 students enrolled in non-science curriculums at the college. Chemistry led the list, 57 percent having had a high-school course; biology, general science, and physics followed in that order, having been studied by 45 percent, 38 percent, and 29 percent of the group surveyed.

Changes in the Secondary-School Science Curriculum

Not much evidence of a changing curriculum in high-school science emerged from that data collected and presented in the Office of Education report (22). However, a total of 135 of the 715 schools in the sample reported one or more science offerings in addition to standard courses in general science, biology, chemistry, and physics. Most frequently reported were "applied" courses, such as applied physics; next in order of frequency was physiology; then came courses in "related science." Also reported were offerings in physical science, earth science, plant science, and five other subjects. Johnson found that all courses offered in addition to the four standard courses could be classified in three groups: physical science, "broad science," and biological science. Of these, physical science was offered in the greatest number of schools—61 in all; 49 had "broad science" courses; and 25 had additional courses in biological science.

As a status study, the Office of Education survey was not geared to the discovery of foci of change; it could hardly be expected to reveal promising innovations in individual school systems. In another report, however, Johnson (21) indicated that he could identify an increase in the number of general courses in high-school science, and also a growth of the two-track system of parallel science courses. A two-track system in the sciences in the senior high school has been discussed by the Cooperative

Committee on the Teaching of Science and Mathematics (30): one track, for students whose interests suggest careers in science, would be the three-year sequence of biology, chemistry, and physics; the other track, for students who will be "educated laymen," would be a two-year sequence of biological and physical science. This Committee has not recommended the double-track curriculum, but it has recommended that two years of science be required of all pupils in the senior high school (1).

Studies carried out as a part of the Illinois Secondary School Curriculum Program led Burnett and Sanford (9) to point out that the contributions of science teaching to an individual's life must at present be made no later than in Grades IX and X. Accordingly, various Illinois schools have undertaken modifications in their science curriculums. These range from experimental modifications of standard courses in chemistry and physics to core programs that pay no attention to subjectmatter boundaries. Grant (18) reported that a required course in health science has replaced ninth-grade general science in a four-year high school with 3000 pupil population; she did not state what provision was being made for including in the pupils' programs the principles of physical science ordinarily developed as part of ninth-grade general science. Lowry (29) reported that, in a four-year school with an enrolment of 1000, biology was shifted from Grade X to Grade IX, replacing general science; and a physical science course was introduced in Grade X. He implied that all students would study biology under this plan, but did not indicate whether the physical science course is required or elective.

Laton and Powers (27) were able to classify the curriculum changes in the schools with which they worked as of three kinds: the introduction of new interdepartmental courses, almost all of them centered in a study of the community; the development of new science courses; and changes in emphases within existing courses. They had no doubt as to the basic cause of these curriculum changes: the teachers themselves had changed as a result of their own study of communities, adolescents, and the persistent problems of people in the present world. Klohr (23) investigated the effect on curriculum change of the resource unit, which may be described as suggestions for teaching about some broad area of experience, so organized as to serve as a source of ideas, material, and procedures for teachers planning their work. Resource units were found to be effective agents of curriculum reorganization where used, but their use was not widespread.

The Nature of High-School Science Courses

After studying the biology and chemistry courses given during the school year 1946-47 in a representative sampling of Minnesota high schools, Anderson (2) concluded that these courses were "far from ideal." Two of the shortcomings he identified were the absence of differentiation among curriculum materials for groups of varying interests and abilities,

and the failure to direct instruction toward the development of understanding of principles and acquisition of scientific attitudes.

No other studies similar in scope to Anderson's have been reported recently, and it may well be that conditions in general are as far from the ideal in other states as in Minnesota. However, there have been reports of promising practices in various school systems. Miller and Dresden (35) described the use of current materials in chemistry classes; the purpose, to develop increased understanding of principles, was apparently realized. Mohler (36) reported the introduction of an experimental unit on mental hygiene in a high-school biology course; the unit was built around responses to two sets of questionnaires relating to the psychological problems of adolescents. Subarsky (55) described an experiment in a New York high school, in which material on race and culture was taught in connection with biology. That the inclusion of such material was indeed an innovation is clear from the report of a survey by Nagler (39) of biology courses in academic high schools in that city: he found that fewer than 10 percent of these schools included a unit on anthropology in the biology course, that the average time devoted to the unit where taught was four days, and that less than half the unit was concerned with the study of race and racism. In schools cooperating with Laton and Powers (27), the most common change in biology courses was the inclusion of material on human growth and development, either as an integrating theme for a long period of study or as short units of work. Another modification in these schools was stress on the interrelation of plants and animals, often as a new approach to the study of conservation.

While biology appears to be the high-school science course which is most frequently modified, evidence suggests that physical science is the course being introduced most often in high schools. Descriptions of such innovations were given by Laton and Powers (27), Griffiths (19), and Updike (56); other courses were reported in a recent symposium on practices and problems in teaching modified courses in the physical sciences (44). In the latter account, certain conclusions and inferences were stated, as follows: (a) efforts at modification have taken the form of classroom experimentation rather than of controlled research; (b) attempts at evaluation of results have not been objective nor statistical, and their validity and the conclusions drawn from them are suspect; (c) while there was general agreement that courses in the physical sciences should be integrated with respect to a basic theme, there was no evidence of an emerging pattern of integration; (d) the roles of textbook, laboratory work, and field trips in the teaching of physical science have not yet been clarified.

A few other "new" courses have been described. McGrath (33) considered geology of exceptional value, especially as a laboratory science in a core curriculum. Feifer (15) reported the introduction of a course in the history and development of science, offered as the fourth year of science in a specialized high school (the Bronx High School of Science).

The course was built around major concepts, such as changes in man's conception of the universe, the evolution of modern theories of matter and energy, and the growth of ideas concerning the causes of disease.

Science for General Education in Colleges

College science courses designed for general education have been of increasing importance in recent years. Their number and nature were investigated by Bullington (7) in a study made under the auspices of the Cooperative Committee on the Teaching of Science and Mathematics. This study showed that in 1948 over half the four-year colleges in the United States offered general-education science courses, most frequently as a program consisting of companion courses in the physical and biological sciences. In a follow-up of a 1938 study of generalized science courses in four-year state teachers colleges, Reynolds (50) found an increase of 60 percent in average enrolment, without a corresponding increase in the size of the student body.

Bullington (7) analyzed 150 general-education science courses, distributed among 83 liberal arts colleges and 23 teachers colleges. He reported the most common types of teaching approach to be, in order of prevalence, the subjectmatter survey, in 42 courses; the study of selected units, in 31 courses; the study of selected problems, in 20 courses; and the historical approach, in 11 courses. A combination of these procedures was used in 30 courses.

Of the four types of approach which Bullington identified, three may be grouped as "block-and-gap" methods; that is, concentration on selected material while consciously omitting other material which may be of equal worth. It is evident that in the majority of the colleges considered in Bullington's study, the general-education science courses were selective rather than comprehensive in character. To the objection that any block-and-gap approach is inadequate, Conant (10) replied that a choice must always be made as to what to teach, since it is impossible in any event to cover all the available or even all the desirable material in an area. Rogers (51) pointed out that an essential of an effective block-and-gap course is careful and adequate treatment of the blocks, and that another essential is connection of the blocks: discussions and investigations, historical studies, ideas and information carried from one block to another, all of which help to show the organic structure of science. Without such interconnection a block-and-gap course may become an emaciated survey course—an unsatisfactory "smörgåsbord."

Hatch and Cope (20) described the development according to Rogers' scheme of a physics course built around the study of the atom; their report dealt in some detail with a method of making the transitions from block to block. Blisard (6) used the problem of housing as the central block in an experimental physical science course, turning to the block-and-gap procedure because a survey course had been found ineffective with respect to such objectives as growth in the ability to identify problems

and to plan and carry out investigations. Test results showed not only that broad objectives were achieved more effectively by the block-and-gap course than by the survey course it replaced, but also that the range and depth of subjectmatter learning in the physical sciences was greater than it had previously been. Perlman (48) reported a course consisting of a series of units, each of which comprised an integration of the various sciences about a central interest vital in students' everyday life, as, for example, an integrated unit dealing with the human body.

The historical approach to the teaching of science has been most intensively developed under Conant's leadership. In a progress report on a general education course in the physical sciences, Conant (10) stated as a basic assumption the premise that study of the way in which certain scientific ideas have been developed will lead to an understanding of the processes by which the experimental sciences have advanced and are advancing. Because the stress in the course is on methods, material from various fields of science is considered; because understanding of processes is possible only in terms of mastery of content, the physical and chemical principles underlying the development of ideas are presented. To keep the factual content relatively low, so that comprehension of generalizations rather than memorization of facts may be fostered, examples are chosen from the history of science (for example, from the 17th Century) instead of from modern developments. Experiences with the case-study method have indicated that there is no inconsistency between this approach and a treatment of scientific topics in a continuous pattern which enables the student to recognize that science is both a historical growth and an exploration of natural phenomena. In a recent discussion of the work at Harvard, Nash (40) pointed out that the case-study approach calls attention to the factors that delay as well as to the factors that promote the progress of science, an important awareness on the part of laymen in the modern world.

Among the criticisms of Conant's course is one to the effect that the approach does not adequately capitalize "the potentialities inherent in a freshman's desire to explore those problems that lie at the interface between epistemology or metaphysics on the one hand and physical science on the other" (10). With this criticism in mind, Van Deventer (57) included as a major goal of a general biology course an understanding of the relation of science and science-generated ideas to the world-view of modern man. In reporting his experiences with this course, he stated that while historical material was not its core, such material was used freely and profitably when necessary for the clarification of a problem under consideration.

Testing To Measure Achievement of Aims

The use of objective tests is no longer limited to measuring the acquisition of information. Woodburn (59) reported modifications and adaptations of objective-type items to test for ability to apply principles, recog-

nize relationships, translate observations into generalizations, and evaluate generalizations. Levy (28) described the chemistry tests of the Educational Test Service with special reference to testing application of knowledge in various situations. Friedenberg (16) discussed the preparation of a battery of test items designed to measure understanding of the basic nature of biological science. The test items were found to be discriminatory both for students who had taken a college course with such understanding as a stated goal and for those who had not, and to measure increase in understanding as a result of taking the course. However, they did not measure subsidiary skills such as the ability to detect meaningless statements and the ability to identify definitions not in classic form.

Considerable attention has been given to the problem of measuring the ability to think critically. Burke (8) analyzed certain items which have been used in an effort to measure this ability, and concluded that many of them actually measured knowledge of subjectmatter. He pointed out the desirability of presenting the necessary facts as a part of any item intended to measure critical thinking. Noyce (46) described a kind of objective test in organic chemistry which has been found effective in requiring students to think critically with the information they possess, and suggested adaptations for use in high-school chemistry courses. Verduin (58) advocated the use of open-book tests, in which students are required to respond to objective items; for example, to determine whether the data in a certain table support a given conclusion. Acting on Verduin's suggestion, Smith (53) prepared such a test for use in high-school biology classes; no reports of its use have yet appeared. Read (49) analyzed statements generally accepted as descriptive of scientific method, and concluded that all involve certain discriminatory choices. He then built a series of nonverbal tests around these choices; each test posed a problem to be solved by the classification of photographs.

Edwards (13) reported the construction of two tests designed to measure the ability of high-school students to think critically with the facts of science. One test consisted of matching principles with descriptions of phenomena, and was found to be sufficiently reliable for use with individuals. The other consisted of items calling for judgments as to which of two opinions was better in the light of given statements to be assumed true; this test was found sufficiently reliable for group use. Both tests appeared valid to the extent that they did not measure either intelligence or school achievement. They were administered in preliminary form to 200 students in Grades IX thru XIV and in final form to 1000 students in Grades X, XI and XII. In both forms the range in any one grade completely overshadowed any increase in mean score from grade to grade.

Dunning (12) developed a "test of scientific thinking" in two parts: one concerned with the ability to interpret data, the other dealing with the ability to apply principles. The test was administered to 109 freshmen in a college physics course, each of whom was also rated independently

by two laboratory instructors on his ability to interpret data and apply principles in actual laboratory situations. These ratings correlated with the scores on the test to the extent of .7. The scores on the test were also compared with scores on the Strong Vocational Interest Blank, using the scientific interest key, and with scores on a test of general reading ability, on Thurstone's primary Mental Abilities Test, and on a fact test. Correlations were low in all cases. The correlation between the two parts of the scientific-thinking test was also low, thus affording justification for separate appraisal of the specified abilities.

If scientific method is operative in the thinking of students, it may be expected to result in changes of opinion when pertinent new knowledge is acquired. Accordingly, Solomon and Braunschneider (54) surveyed the racial, religious, and national prejudices of students in a college basic biology course, using a social-distance scale. The expressed attitudes of a control group of 1091 students were compared with those of an experimental group of 1334 students. The experimental group had studied the biology of the races of man presented with the intent of applying the scientific method to the problem of prejudices in this area. The data indicated that the teaching resulted in lessened prejudice; however, the investigators recognized that they had not measured the "staying quality" of the change, nor had they measured its expression in overt behavior. Barkley (4) studied the responses of freshmen college women to the Thurstone attitude-toward-evolution scale, administered as a pretest and as a post-test to five groups: students in biology classes, students in chemistry classes, those taking both biology and chemistry, those enrolled in mathematics but not in a science, and students in a commercial curriculum including neither science nor mathematics. The first three groups changed from a prevailing attitude of neutrality or doubt to an attitude favorable to the acceptance of evolution; the change in the mathematics group, altho in the same direction and from the same position, was not significant. There was no change in the commercial group, which differed from the others also in showing an initial attitude of antagonism toward evolution. No significant difference was found between students who had had biology in high school and students who had not.

Studies by Anderson (2, 3) sought to identify factors involving achievement in biology and chemistry. These studies are reviewed in detail in Chapter II.

Mason (32) used a test of information to analyze the needs of students in a college biological science course. When the test was given during the early part of the course, he found that the various areas of subject-matter could be ranked with respect to student knowledge in this order: interrelationships of living things; economic biology; evolution; coordination and adjustment, and reproduction; and parasitism. When he compared the pretest scores with scores achieved on the same test during the closing week of the course, he found that the greatest gains in information had taken place in the area of reproduction; the other areas could be

arranged with respect to increase in student knowledge in this order: heredity, evolution, coordination and adjustment, parasitism, economic biology, and interrelationships.

Noll (45) reported a study of the measurement practices and preferences of 390 high-school science teachers, made as a part of a nationwide survey of 2303 high-school teachers in 207 schools. He found that the science teachers commonly used both essay tests and objective tests: only 1 percent used no objective tests and only 13 percent used no essay tests. In their objective tests they incorporated many types of items; they favored completion, short-answer, and multiple-choice items over matching and true-false items. They depended to some extent on other evaluation instruments than tests: 48 percent used cumulative pupil records, and 44 percent used rating scales. But these teachers revealed a lack of information about standardized subjectmatter tests and a disinclination to administer them. Altho only about 36 percent of the teachers said that they never used standardized tests, Noll found a strong indication that the others used these tests only incidentally in evaluating student achievement. In their use of standardized tests, science teachers were found to be somewhat behind teachers of other subjects; on the whole, however, their measurement practices compared favorably with those of their colleagues in other areas.

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CHAPTER II

Instructional Procedures in Science

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In view of the extensive and thoro work being done by the National Association for Research in Science Teaching in the collation of unpublished research—which data will be made available to workers in the field in the form of reports—the authors of the present chapter made no attempt to secure unpublished studies for review. The review presented is based upon a study of well over 400 published studies which, by titles, appeared to merit consideration for inclusion. Only those are here included in which some measure of empirical data is reported in terms of reasonable validity. Only three reports which might be labeled as descriptive are included in the present chapter. These are included because they provide insights into new fields or because they form a basis for the possible launching of empirical studies.

The studies reported in this chapter vary considerably in the soundness of their conception and in their execution. It should be stressed that the careful use of sound research design will more surely chart the way to more effective instruction in science than will the accumulation of hundreds of partially valid studies. Some of the research here reported is of excellent caliber. The first study reported below is a good example of a carefully conceived and comprehensive study that utilized newer statistical technics and that produced at least presumptive data of significance. It is to be hoped that more of this caliber will be forthcoming.

Classroom Technics and Other Factors Related to Student Achievement

Anderson (2) sent a one-page questionnaire to teachers in 21 communities in 12 states who had previously participated in trying out the experimental forms of the author's new chemistry examination. Usable replies were secured from 17 teachers in eight midwestern and eastern states. No claim is made by the author for the representativeness of the sample. Anderson attempted to determine what factors reported in the questionnaires affected achievement in the 17 classes. Variance and co-variance statistical technics were used. Differences in intelligence of the students were equated out. The author found that the students achieved significantly more in chemistry when: (a) they were enrolled in large schools; (b) the teacher's load was in the lowest quarter of the distribution; (c) the teacher was in the upper quarter of the distribution in terms of college hours of chemistry taken; (d) the same for total college credit in sciences; (e) class size was in the lower quarter of the distribution; (f) students used a laboratory manual; (g) students received laboratory work

rather than demonstrations alone; (h) students had two double laboratory periods a week rather than five periods a week for both laboratory and class work; (i) students used a macro- rather than a semimicro-approach. A total of 15 such comparisons were made. In reference to points (c) and (d) above it should be noted that the lowest quartile and highest quartile for semester hours of chemistry taken in college were 10.5 hours and 31.5 hours and the same for total science courses taken were 52.5 hours and 84.3 hours respectively. Thus the highest quartile represented a not excessive preparation in chemistry in terms of a total college program and in terms of the balance with other science courses. The lowest quartile represented approximately the beginning year of college chemistry only.

In a study previous to that reported above, Anderson (3) secured comprehensive data on a representative sampling of 56 Minnesota high schools. His study provided a description of practices in the teaching of biology and chemistry and a description of teachers of these subjects in terms of their backgrounds of preparation and experience. In one phase of this exceptionally well designed and executed study Anderson secured responses from some 91 teachers of biology and of chemistry to some 58 items. Anderson found that the median number of quarter hours of preparation in college biology of the biology teachers was 27 while the median number of quarter hours in chemistry of the chemistry teachers was 23. Fifty-five percent of the biology teachers and 91 percent of the chemistry teachers followed a workbook or laboratory manual. Laboratory work accompanied classwork in 65 percent of the cases in biology and in 51 percent of the cases in chemistry. Only 5 percent of the biology teachers and 13 percent of the chemistry teachers provided laboratory instruction preceding the equivalent classwork. A variety of laboratory procedures were used but most teachers in both chemistry and biology followed the experiments as outlined in a manual or textbook. Eighty-three of the 91 teachers of biology and chemistry indicated that the laboratory and the classroom were physically combined. Only 12 percent of the teachers indicated that they sponsored some form of a science club. Fifty-five percent used field trips. Sound movie projectors were the most available teaching aid yet their median use was only six times a year by the chemistry teachers and 10 times a year by the biology teachers. Twenty-six percent of the reporting teachers indicated a "good supply" of science books in the library. Forty-four percent indicated a "fair supply," and 30 percent indicated a "poor supply." No differentiation of instruction for college preparatory and terminal students was provided by 27 of 58 responding biology teachers and by 22 of 47 responding chemistry teachers.

On the basis of achievement scores of 1980 biology students and 1352 chemistry students Anderson (4) utilized the same technics as were reported in determining certain factors related to achievement. Students achieved more in biology when the number of laboratory hours received was in the upper quartile of the state distribution; the time of laboratory

instruction was not found to be significant; and, unlike the data secured in Anderson's other study (2), there was no difference in student achievement in biology when those using laboratory manuals were compared with those that did not use laboratory manuals. Scores on the chemistry test, however, favored those that used laboratory manuals. As 91 percent of the chemistry teachers used a laboratory manual this datum may be of doubtful validity, for other uncontrolled variables may have operated.

Space limitations gave Ahmann (1) a basis for comparing the effectiveness of instruction in college chemistry when students carried on laboratory work and recitation work at the same laboratory desks in three two-hour periods per week while another group of students followed the more conventional pattern of four one-hour recitation and lecture periods together with one three-hour laboratory period a week. The same textbook, laboratory manual, equipment, and facilities were used in both classes. One hundred forty-seven men, engineering freshmen, in each group were given the same final examination. Statistical analysis showed the methods to be equally satisfactory in terms of student achievement.

Miller and Dresden (20) studied certain apparent results of instruction in physics and chemistry in which the use of advertising materials, pamphlets, periodicals, and similar current materials was emphasized. Over the three-year period of the study one day a week was devoted to topics for which the current materials were the basic study matter. Considerable assistance was given the students in the proper use of materials and in developing their ability in terms of group process, individual initiative, and leadership. The experimental group consisted of students of one school in California. Students from two other California schools comprised the control group. Altho no evidence is reported of the comparability of these groups in socio-economic status, aptitude, reading ability, periodicals commonly used in the home, etc., and altho the IQ's of the experimental and control groups were not equated, the IQ's of the former group were reported to average 105.0 while that of the two groups constituting the control group averaged 109.2 and 113.5 respectively. Comparison of the groups on the basis of scores made on the Cooperative Physics tests and the Cooperative Chemistry tests showed that the regularly accepted curriculum achievement by physics and chemistry students is not lessened by devoting one-fifth or more of the time to the study of current materials. Results from the use of the *Time* Current Affairs Tests indicated that the experimental group had a superior knowledge of current affairs each of the three times the test was given. The author sent a questionnaire to 83 graduates of the experimental classes of the previous two years and received 61 replies. The graduates were spending, on the average, 9.9 hours per week on current materials according to their replies. Noncollege graduates averaged 13.4 hours according to their replies. Science reading in current materials was represented as the chief topic of interest of the graduates with "Universal Military Training" and "Russia" running a poor second. It was the judgment of the authors that interest

was developed in current periodicals, current affairs, and current science, and that this interest tended to persist after the students left high school.

Smith (27) reported two studies bearing on the relationship between intelligence and the learning that results from the use of educational motion pictures. One of these studies was the author's own which was primarily concerned with a determination of the relative effectiveness of teacher demonstrations and motion pictures in producing learnings. The other was a study co-sponsored by the University of Nebraska and the state Department of Public Instruction. Five different tests of factual information and understandings of generalizations were employed. It was found that intelligence and gain in factual information and understandings were positively related and were independent of the methods of instruction utilized. The Smith study disclosed, clearly, that there was no statistically significant difference in the correlations of gain and intelligence in the film sections of students when compared with such correlations in the demonstration sections. Neither films nor demonstrations produced learnings superior to the other with either bright or dull students.

Hellman (15) attempted to compare the results of a science test administered to students living in urban and in rural areas in order to determine the significance of this environmental difference in the four categories of factual knowledge, conceptual abilities, interpretation of charts, and ability to think thru abstract questions. The author equated the two groups in terms of size of schools, equipment available, and the use of standard textbooks and held that any differences obtaining in the results would be due to environmental conditions related to the living area of the students. No significant differences were found except in the area of abstract thinking.

Baar (5) attempted to compare the results of three general "enrichment" technics in instructing four classes of ninth-grade general science students each semester over a period of two semesters. The achievement of the experimental and control groups was measured by a scientific attitude scale; a social implications of science test; the Cooperative General Science test; and a test of applications of principles in physical and biological science. For the first semester the control group was taught by lecture, demonstration, and textbook recitation. One experimental class was taught thru a problem approach technic; another by giving considerable attention to the social implications of science; and the third by "differentiated enrichment activities." During the second semester the control group continued as during the first semester; but two of the three enrichment technics were combined in each of three experimental classes so that each of the three technics were combined with one of the other two. Twenty students from each group were equated on the basis of mean reading grade, initial test mean, standard deviation on initial test scores, and sex. Each first semester experimental group showed greater growth in ability to determine cause and effect relationships than did the control group altho the differences were not statistically significant. When the experi-

mental methods were combined in the second semester, the groups employing the problem approach as one of the two methods showed statistically significant gains in this ability over the control group. Baar concluded that the ability to carry on the many kinds of activities employed in the study of science is specific rather than general and that the type of reasoning used in problem-solving is different from the reasoning used in applying scientific principles. The problem approach showed no significant advantage over the control method in improving ability to apply scientific principles, but it was superior (altho not statistically significant) in teaching understanding of social implications of science, achievements of science, and in tackling scientific problems.

Friedenberg and Smith (14) reported data from the former's study of a technic for developing a chemistry course at the junior college level designed to meet the needs of students. A functional approach was used in which a selected reference shelf was used instead of a textbook. The choice of reading was left to the students. No daily assignments were made, and student need determined the course organization. An elected student committee evaluated the course periodically. Each student in this experimental course was matched on certain relevant particulars with a student in a conventionally organized course. Originally there were 46 matched pairs, but drop-outs reduced the number to eight pairs by the end of the study. The authors report that examinations given to the two groups disclosed a superiority of the experimental group in the ability to use chemistry intelligently as consumers of goods. Detailed information regarding the procedure was not presented in the article, and the small number of cases provide only presumptive data. Considerable investigation is needed in the area of this study. Limited comparative studies would be of less value (due to the difficulty of controlling variables) than would carefully designed and controlled descriptive studies with adequate technics for evaluating shift in the direction of the objectives of instruction.

Status of Elementary Science Teaching

Only one usable study related to the status and teaching of elementary science was discovered in the literature of the review period. Lammers (17) interviewed a representative sample of 100 teachers of the first six grades in 81 public schools in Massachusetts. The interview technic was held constant and consisted of 38 questions. He found that 74 percent of the teachers felt free to use science materials in their instruction; but that such materials were introduced by means of special science periods ranging from 15 minutes to 120 minutes per week, and by correlation with other subjects. About half of the teachers relied on correlation and incidental teaching for science instruction. More than half indicated a preference to base their science instruction on the interests of children. The extent of science work in the professional training of the teachers

was reported. Science topics were taught chiefly thru reading and discussion, altho some mentioned demonstrations, experiments, field trips, and films. The frequency with which these latter aids were used was very low, according to the author. About 62 percent were found to have "fairly adequate" textbooks and reference materials.

Science Teaching and Attitudes

Only one study reporting empirical data on attitudes toward racial and religious groups was available in the literature of the review period. Solomon and Braunschneider (28) attempted to determine if attitudes of students in biology at Michigan State College related to ethnic, racial, religious, and nationality groups would shift as a result of instruction designed to apply the scientific method to such prejudicial attitudes. The control and experimental groups were unequated, and the authors indicate that more adequate control was needed. The two control groups were students in the first and second quarters of biological science in which nothing was taught on the races of man. The experimental group consisted of third quarter students who were helped in applying the scientific method to the problem of racial prejudice. A questionnaire was given to all three groups of students simultaneously. This instrument was a "social distance" scale on which the respondents indicated whether or not an individual in a given national, racial, or religious group should be permitted to engage in each of 12 activities ranging from school attendance (with majority group individuals) to dancing with a student not of his own group. One thousand ninety-one students comprised the control group, and 1334 made up the experimental group. Thirty-two percent of the control group students indicated that members of the nine specified national, religious, and racial groups should be permitted to participate in all 12 activities proposed. Forty-two percent of the experimental group so indicated in all 12 activities. The authors' conclusion was that teaching for the purpose of applying the scientific method to problems of prejudice does have a positive effect in the direction of the objectives.

Mohler (21) reported the use of group methods of instruction in an experimental unit on mental hygiene. The experimental unit was developed on the basis of interviews with students enrolled in biology classes over a two-year period and was built around the needs and desires of the students as thus expressed and further revealed in anonymous responses to two questionnaires. The experimental unit was used in three biology classes taught by three different teachers. A pretest and post-test to which all students responded anonymously constituted the main basis of judging the effectiveness of the instruction. The instruction included individual investigations in areas of student concern; laboratory exercises chiefly concerned with sensory impressions; group analysis of reproductive physiology; and group analysis devoted to increased "understanding of one's self." An attempt was made to keep the materials studied related to student experience and background and to avoid theoretical psychology

as such. The students engaged in individual consultations with the teachers, engaged in considerable library research, and worked in small groups in which common problems were discussed and ideas exchanged. The teachers assisted the students in improving their group work and the classes engaged in analysis of the group process.

According to the author the students gained new insights into their behavior, faulty knowledge was corrected, and the major objectives of the unit were apparently achieved. In the pretest only 57 percent of the students indicated that they had knowledge in regard to sex questions. Eighty-seven percent so indicated in the post-test. Forty-eight percent indicated, on the pretest, that they had personal problems. Seventy percent, on the post-test, indicated that they had reached some understanding of their problems. Only 20 percent indicated, on the pretest, that they knew the elements of mental hygiène. Seventy-two percent felt that they had a better concept of mental hygiene at the end of the unit. On the question: "Are you happy?" 73 percent yes responses on the pretest changed to 87 percent on the post-test. On the question: "Do you like school?" the yes responses increased from 80 percent to 95 percent.

Critical Thinking and Scientific Method

Edwards (13) has reported the general procedures used in an experimental college course in science designed to serve as general education for prospective art teachers. His report includes both objective and subjective evidence of results of the instruction. The 30 students and the instructor engaged in informal discussion of the objectives of the course and worked primarily in small groups of flexible composition. Problems of the immediate environment were attacked, and students developed group projects. Pretest and post-test scores disclosed growth in knowledge of scientific facts. The tests used were developed by the author, and only raw scores and the mean are reported. Pretests and post-tests of critical thinking (the instrument was not reported) showed no change in this particular, altho improvement in this skill was consciously sought thruout the semester. The report of the study does not provide information on which a basis for judgment of the validity of the instrument might be made.

Owens (23) attempted to investigate the relationship between the ability of high-school pupils to recognize scientific principles in test situations and the ability to apply these principles to problematic situations. His study also undertook to determine the effects of directed teaching on the ability of students to apply scientific principles to situations not previously encountered. Owens used 296 high-school students in one public high school for his study. These were in six biology classes and four chemistry classes. The investigator and two other teachers each taught both control and experimental classes. Both control and experimental groups were subjected to the same general teaching procedure, but the students in the experimental group were directed to seek additional prob-

lems in each unit, were directed to state applications of scientific principles to everyday living, were requested to read additional references, to solve additional problems, and to keep a definitely planned notebook containing applications of the scientific principles to everyday living. In addition, the experimental group prepared a summary showing how the applications compiled by each student were related to the scientific principles.

The two groups were matched on the basis of IQ, chronological age, and mental age. Two tests were constructed by the author. One, of suitable reliability, was designed to measure ability in recognition of scientific principles. The other, with a coefficient of reliability of .60, was designed to measure the ability to apply scientific principles to new situations.

Owens found that the students in his study showed greater ability in recognizing scientific principles than in applying them to new situations. He found a significant difference in favor of the experimental group in the ability to recognize and to apply scientific principles to new situations. Students of high measured intelligence were superior to those below the mean in their ability both to recognize and to apply scientific principles to new situations. The author pointed out that the tests used were limited and that more tests of high validity designed to detect ability to apply scientific principles to new situations are needed. He noted, further, that the problem-solving technic was used with both groups and that both groups showed improvement in the investigation.

A fundamental weakness in all studies relative to scientific method and scientific attitude is that there is no clear general agreement as to what comprises these qualities. Lampkin (18) undertook a study of scientific inquiry as it appeared in selected high-school science books. Each textbook was dismembered, and 12 composite books containing fragments of the original books were formed. Twelve readers, six each who were majoring in science teaching and in philosophy, analyzed one each of the composite texts. Each reader was asked to determine what portions of the book represented what steps in the scientific method of inquiry. Altho these readers utilized Mr. Lampkin's detailed formulation of scientific inquiry, there was lack of agreement among them in recognizing and classifying the elements of scientific inquiry. This study seems to show that there is little common agreement among science-educators-in-training, as well as between science-educators and philosophers-in-training on what constitutes scientific method as a method of inquiry, or of its aspects. If this be true, it doubtless accounts, in large part, for the lack of evidence that science teaching has contributed significantly to the development of scientific methods of work. It is obvious that objectives must be clear and well understood before they can be achieved or evaluated.

One phase of Anderson's comprehensive study (3) of chemistry and biology teachers and their work included eight questions on the nature of

scientific method. A problem was included. The 58 chemistry teachers and 55 biology teachers who responded to the questions showed evidence, according to the author, of "a lack of knowledge concerning the scientific method. It suggests that they were busy imparting factual information to their students . . ." apparently to a rather high exclusion of emphasis on scientific method and attitudes.

Reiner (24) compared two teaching procedures with reference to their effectiveness in producing growth in the ability to recognize direct, indirect, and negative cause and effect relationships. The experimental procedure differed from the control in the single respect of including specific training in the analysis of causality related to demonstrations. The classes were ninth-grade general science, and each instructor taught at least one experimental and one control class. There were 169 children in the experimental group and the same number in the control group. The students were equated on the basis of IQ and scores made on an initial test designed to detect ability in causality recognition. The experimental group made greater gains in total ability to recognize cause and effect relationships. Its advantage over the control group was expressed as 1.347 sigmas. Three IQ levels were considered in the study, and the experimental group showed superiority at each level altho the advantage of the lowest IQ experimental group was only 1.006 sigmas over the control group. Boys surpassed girls. The superiority of the experimental groups was in terms of the recognition of indirect and negative causality only, for the control group made a slightly greater gain in recognizing direct causality.

Bingham (6) reported tentative and preliminary findings on a cooperative project designed to determine whether or not certain elements of the scientific method can be taught directly thru the use of a specific instrument designed for teacher use in connection with selected demonstrations. Each instrument was, in essence, a brief problem unit such as "How does water affect a hot fat fire?" Direction sheets provided to the teachers of both experimental and control groups proposed the same steps to be followed in connection with demonstrations related to the problem units with the exception that the experimental groups were given an opportunity to consider the various steps of scientific method related to the demonstrations. Test sheets provided the basis of determination of student achievement in the use of the scientific method. The authors analyzed only one teacher response in the report being considered. This case compared 39 ninth-grade children in the experimental group with an equal number of students in the control group. There was no effort at equating possibly related variables. Preliminary test results were compared with test results following the demonstrations. The experimental group was found superior in recognizing assumptions that underlie conclusions and in applying conclusions satisfactorily but showed little advantage over the control group on other measured factors.

It is encouraging to find continued studies of critical thinking and pro-

cedures of inquiry in the literature. It is to be hoped that studies in the future will be sounder in conception, better executed in terms of control of possibly related variables, and be based upon more explicitly stated and validated assumptions and criteria. More valid technics of evaluation are urgently needed. Sound research design is necessary in this important and difficult field of investigation. Large numbers of studies of low validity are misleading in their conclusions.

College General Education Courses

The general ferment in education continues to affect the colleges. General education courses are growing in number and experimentation with various types of courses continues.

Under the sponsorship of the Cooperative Committee on the Teaching of Science and Mathematics of the American Association for the Advancement of Science, Bullington (8) undertook to determine the status, trends, objectives, content, and procedures of general education college science courses thru the utilization of a comprehensive questionnaire. This inquiry form was sent to 967 four-year colleges, universities, and teachers colleges thruout the United States. Replies were received from 660 schools. Information on 60 additional schools was secured from perusal of catalog statements. Of 720 schools for which data are available (this represents 74 percent of the 967 four-year colleges and universities in the United States), 59 percent offer general education courses of some kind. Two hundred twenty-one of the schools report both biological and physical science courses designed for general education purposes. Eighty-one schools report a general course covering both biological and physical science. Fifty-eight schools report only biological science courses, and 42 report only physical science courses. Sixty-three schools report specially designed single-subject courses. Bullington found that general education courses in the sciences are much more prevalent in teachers colleges than in other schools. Eighty-one percent of the teachers colleges reported such courses. The author obtained detailed information about 150 courses from 103 colleges of all sizes. The subjectmatter survey approach was the most commonly used method of teaching in these courses. It was reported as the only method used in 42 courses of the 150. The study of selected units ranked second in frequency with 31 courses employing it. Twenty courses used selected problems as the basic approach, with an additional 13 using this method in combination with one or more additional methods. The historical development approach was used in 11 courses. Bullington (9) reports that the most frequently used methods of determining subjectmatter content are, in order of prevalence: (a) a determination of student needs; (b) the selection of a textbook, (c) a study of the interests of students in the class, and (d) the use of material selected to survey a field of science. Bullington reports the typical course as one year in length, given by two or more teachers, and employing demonstrations, visual aids, field trips, and laboratory

activities in addition to lectures and discussions. Student opinion of the courses was sampled thru the administration of a questionnaire to 1200 students in 14 courses (9, 10). Seventy-seven percent of the students ranked the courses as above average in the choice and utilization of instructional procedures and materials.

Another general survey of college general education courses in the United States was conducted by Washton (29). His findings were approximately the same as Bullington's in most particulars. Washton developed a questionnaire designed to elicit certain facts about college science courses designed for general education. Questionnaires were sent to 500 liberal arts colleges distributed over the United States. The author received an 84 percent response. Forty-six percent of the responding colleges had no general education or survey-type courses in science. Forty-five percent had one or more survey or general education science courses. Of these 190 colleges, 71 offered a general education course in the biological sciences; 61 offered such a course in physical sciences; and 74 offered courses that combined both the biological and the physical sciences. Most colleges reporting general education courses indicated that these ran for two semesters. The majority of the colleges omit laboratory instruction from the general education science courses. Lecturing assumed much more time than discussion in the majority of the courses and most of the respondents indicated the chief purpose of the courses as informative. Thirty-two of these courses were reported to enrol over 100 students in the lecture sections. However, the majority reported lecture sections of less than 50 students. In the physical sciences only 11 institutions reported the utilization of demonstrations while 12 additional institutions reported demonstrations in courses that combine the biological and physical sciences.

Another study designed to determine the status and trends in general education science courses at the college level was conducted by Reynolds (25) who sent a questionnaire to all four-year state teachers colleges in the United States. Replies were received from 79 colleges (60 percent of the total) well distributed over the United States. The author compared the results of this 1949 study with a similar survey he had made in 1938. He found that 85 percent of the schools required students to take generalized science in 1949 while only 78 percent had this requirement at the time of the previous study. Twenty percent of the schools required the course for elementary majors in 1949 as against 11 percent in 1938. In 1938, 47 percent of the class time was devoted to lecturing, 41 percent to lecture-demonstration, and 10 percent to individual laboratory work. In 1949 this had changed to 56 percent devoted to the lecture method, 23 percent to lecture-demonstration, and 14 percent to individual laboratory work.

Conant (11) has presented a progress report on the use of the case-history method in teaching the principles of the "tactics and strategy" of science to a group of 150 nonscience major freshmen and sophomores

as a part of the new general education program at Harvard College. The procedure in this course, suggested earlier in Conant's *On Understanding Science*, is an intensive study of several cases in the history of science which illustrate the general nature of science. The students turned in two unsigned questionnaires which, together with student reactions in the discussion periods, form the basis of the evaluative aspects of the progress report. According to Conant the better students had greater interest in the course and appeared to benefit most from it. The bulk of the students placed this course second or third in terms of interest, among the four they were taking.

Among the fields that should be investigated in connection with college general education science courses are the following: (a) status, training, and strengths and weaknesses of instructors of such courses; (b) evidences of strengths and weaknesses of the several types of general education courses from sociological, psychological, and empirical bases; and (c) detailed descriptions of promising technics together with valid and reliable evidences of the effectiveness of such procedures. There are little or no data of worth on any of these points at present.

Teacher Training

Curtis (12) utilized a questionnaire to determine the judgment of elementary teachers in the District of Columbia on the adequacy of their science training and on related matters. Five hundred sixty-nine teachers returned the questionnaire. Four hundred fifty-nine of these felt that appropriate in-service training should be provided on elementary science. Workshops were specified most commonly as the means preferred for this training. Five hundred nineteen of the respondents stated that they believed that preservice training in science for elementary teachers should be strengthened, while only 36 replied in the negative. In order of frequency of mention, the following represent these teachers' viewpoints on areas needing stress in professional training related to science teaching (over 300 listed each one): the use of environmental materials, laboratory experience, laboratory construction, collection of resource material, sources of audio-visual aids, technics of field trips.

Blisard (7) provided a general description of a college general education course in physical science attended primarily by prospective elementary-school teachers. A subjective evaluation of the results of the course was given.

Salem (26) utilized questionnaires formerly developed and administered to science teachers in the United States by Burnett in order to study the opinions of biology teachers in Egypt and to compare their responses with those of American science teachers. Two separate questionnaires were used in the Burnett study. Salem's study used these, in slightly modified form and, in addition, added another section dealing with the aims and objectives of biology teaching in Egypt. His findings were that:

(a) an overwhelming majority of Egyptian biology teachers (like American science teachers) hold their chief responsibility to be that of facing the problems and interests of youth and society and bringing their specialized competencies as teachers to bear on these problems and interests; (b) the six issues most commonly chosen by Egyptian biology teachers to be avoided entirely were conflicts between traditional religions and science over views of the universe and man's place therein, comparative progress of science under various political systems, racial prejudices, relative merits of various healing arts, questions of moral codes and ethical principles, and present social maladjustment brought about by the impact of science on society; (c) these very issues were, with one exception, those held to be of the greatest instructional value to young people (practically the same findings as in Burnett's study of American science teachers, both in the areas held of high significance and in avoidance); (d) Egyptian science teachers held most commonly that the lack of maturity of pupils, insufficient personal knowledge (on the part of the responding teacher), fear of outside pressure groups, and disapproval of parents were their reasons for avoiding these areas of significance in their teaching. These were precisely the same reasons as specified by American science teachers. It should be noted, however, that Salem's study had the same defect as the Burnett study in that these four reasons for avoidance were specified (in the Egyptian study) with no others pegged in the questionnaire. The Burnett study listed six reasons. Both studies provided space for the expression of other reasons but virtually none were provided by the teachers responding in either study. A separate section of each study was devoted to securing the viewpoints of science teachers on such controversial issues as racial differences, socio-economic differences, the immutability of human nature, the control of scientific research, and some aspects of supernaturalism. Responses were tabulated somewhat differently in the two studies. Salem reported that much higher percentages of American science teachers, as opposed to Egyptian biology teachers, expressed opinions that are in consonance with the commonly accepted tenets of science. Salem further reported that the disciplinary or training aim and the religious aim of biology teaching was held by the majority of Egyptian biology teachers along with the more commonly endorsed objectives of science teaching in this country. The belief that college preparation without particular attention to general education should be the goal of the science teacher in the secondary schools of Egypt was expressed by more teachers who had not had education courses than by those who had taken such courses, and the difference was statistically significant.

This study represents one of the few studies on comparative education in science to date. Here is a field that merits considerable investigation. American science teachers know little of what is being done in other countries. The Salem technic of utilizing instruments and procedures already employed in the United States provides an interesting basis for

close comparison. It is hoped that such studies, in the future, will eliminate, where possible, defects in the original instruments and technics.

Descriptive Accounts of Programs and Procedures

Altho most of the specific studies growing out of the work of the Bureau of Educational Research in Science at Teachers College, Columbia University, have already been reported in the literature, the report by Laton and Powers (19) of the experiences and procedures of teachers in 17 secondary schools that cooperated with the Bureau provides an interesting record of general technics and procedures designed to make science teaching more functional. The descriptions include accounts of new emphases within existing courses and the development of new courses, both within science departments and by integrating science with other areas such as social sciences.

Murray (22) used the group process in developing demonstrations based on biological principles previously compiled by Edgar W. Martin and physical principles compiled by Harold E. Wise. The demonstrations were designed to employ simple and easily available materials and were constructed for the use of junior and senior high schools. The study was designed to develop new and improved demonstrations and is descriptive as to process.

Large numbers of colleges have changed from macro-technic in chemistry to semimicro-technic. A fair number of high-school teachers have modified their program in the same direction but there is, as yet, little substantial evidence of the results of the change. A study by Hoff (16), while not providing such data, is of interest at this time, for he undertook an operational analysis comparing the two technics and interviewed a selected group of teachers in central New York State relative to questions they had regarding changing from the macro- to the micro-method. The author then attempted to correlate the questions and to answer them under the belief that the questions raised would be typical of those arising in the minds of most high-school chemistry teachers considering such a change. The author concluded that the advantages accruing to the semimicro-technics far outweigh any presently known disadvantages when compared with macro-technic. It is to be hoped that many teachers, utilizing Hoff's report of questions and his answers, will undertake careful analyses, under suitably controlled conditions, to provide needed information as to the actual advantages and disadvantages of semimicro-technic on an empirical basis.

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CHAPTER III

Materials in the Teaching of Science

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THE development of teaching materials has been expanding rapidly for several decades. The effect of World War II was to reemphasize the value and need of such materials and to sharpen the imagination of teachers and students alike as to the use of these materials in ordinary educational situations. The increasing technological developments of the past few decades have necessitated more materials and have led to relatively new technics in their production. The profession of education has sensed the need for restudying the purposes, usefulness, and effectiveness of teaching materials. The area of science by its very nature has found this need rather acute.

The term *materials* here designates any of the physical devices used in the teaching of science. Within the purview of this study are books, magazines, pamphlets, motion pictures, filmstrips and slides, and laboratory and demonstration equipment. There are, of course, groupings and derivatives of such types of material which likewise are appropriately the subject of reporting where research has been carried out.

Scope of Concern

One of the most significant investigations dealing in part with materials was that by Johnson (8) of the United States Office of Education. A sample of high schools stratified according to size and type provided information on several aspects of the teaching of science in the public schools of the United States. Data were sought from 755 high schools, 3.15 percent of the total in the nation. Usable data were received from 715 high schools, 2.99 percent of the public high schools. The study included in part a determination of troublesome or difficult problems in the teaching of science. A tabulation of the type and frequency of the problems indicated is given.

Of the total number of difficult problems, those relating to books constitute 2.4 percent; those to rooms, 23.6 percent; and those to supplies and equipment, 33.4 percent. If the problems relating to books, rooms, and supplies and equipment are grouped, they constitute 59.5 percent of all the troublesome problems given. It is significant that the major portion of all problems listed by the respondents is in the field of materials of science teaching.

A comparison of the total list showing the type of school and the problems reported by each type indicates that the problems are distributed in approximately the same proportions as the types and sizes of schools in the sample. "This indicates that the problems reported were common to

all types and sizes of schools and whatever can be done to help meet the problems will therefore help all types and sizes of high schools."

Materials for Elementary-School Science

A survey of the problem of teaching materials for elementary-school science was made by Hubler (7).

The study involved 60 teachers from central Connecticut and was concerned with their problems of teaching materials in science. The teachers were from 39 elementary schools in 29 cities, villages, and rural areas. They represented the six grades equally. Twenty-seven questions ranging from the appropriateness of science in the work of the elementary school, thru the problems which prevent the improvement of science instruction, to the expressed wishes of teachers as to the content of a science handbook for elementary teachers were asked.

The respondents agreed on the importance of science in the elementary curriculum, and on the desirability of materials for science instruction. The lack of adequate materials was a problem for a majority of the teachers, even tho they reported that considerable science was being taught in spite of this deficiency. The study revealed a lack of understanding on the part of the teachers as to their needs and ways of meeting them.

A second portion of the study was concerned with lists of recommended materials and their availability.

The needs of elementary teachers and their participation in the preparation of materials was studied by Greenlee (6).

The purpose of this project was to put into usable form a source book of science experiences for the classroom teacher to use in enriching the learning environment of preschool and early elementary-school children.

The major portion of the project consisted of suggested science experiences and interpretations dealing with seven major topics (e.g. "Children's Experience with Soils and Rocks"). A wide variety of experiences was suggested under each topic.

The final draft took into consideration the critical suggestions of 12 classroom teachers and supervisors who read the original manuscript as a whole or in part.

Boer (3) studied the use of sensory aids in teaching science in the primary grades. The children were taught to find the answers to their questions and problems of scientific nature by experimenting. Large charts were made to serve as a record of the basic aspects of their experiments: *what we did, what happened,* and *what we found out.* Story charts were mimeographed and made into booklets for the children. Pictures from magazines were placed on the bulletin board. For example, weather reports in the newspapers were related to the radio reports, to the barometers they had made, and to the weather itself.

Without presenting the evidence in objective form, the author concluded that the children learned to be a little more considerate of each other, listened politely when others were talking, worked together better

in groups, became more alert and observant to things about them, developed the habit of forming conclusions from facts they had learned instead of accepting anything that was told them or jumping at conclusions.

Read (17) made a study of 131 basic readers from preprimer thru the sixth grade, noting the scientific facts, principles, concepts and attitudes *expressly* included, but omitting geography, customs, and home gardens and household pets. The percent devoted to science ranged from 12.8 to 19.4, with an average of 16.5. A table is given showing the distribution among topics of the total number of pages *devoted to science*. A second table shows the form of presentation of the science materials. The author concluded that the books rely too heavily on the biological sciences, particularly on animals. The physical aspects of science were largely neglected. It is interesting and probably significant that little science is taught by experimentation.

Reading Materials for High-School Science

The planning of a series of junior high-school science textbooks was the subject of a study by Neal (16). On the basis of science necessary to general education, he isolated such aspects as health, safety, consumership, and conservation, as well as others. He suggested an organization of junior high-school science textbook materials around typical situations found to be useful in helping children to understand relationships appropriate to general education. Evidence was summarized from policy-making statements on curriculum and teaching. Policy level statements from publications in the field of science education were summarized and utilized to the extent that they contribute to the undertaking at hand.

The second half of the report outlined and illustrated suggested junior high-school science textbook materials intended to serve as resources for general education.

Anderson (1) studied the availability of reading materials for science in a random sample involving 56 of the 483 high schools in Minnesota. A study was made of such adjuncts to science instruction in biology and chemistry classes as the field trip, the science club, library books, periodicals, and visual aids. The study determined in part the judgment of the teachers as to the supply of science books in the school library. The percent of teachers replying in each of three categories is as follows: good supply, 26 percent; fair supply, 44 percent; poor supply, 30 percent. The median number of magazines of scientific nature available to students was 1.64.

A study of the reading difficulty of science textbooks was carried out by Mallinson and others (11). A sampling technic was utilized in connection with the Flesch formula. On the basis of a study of 10 three-book series and two two-book series in junior high-school science, the investigators concluded that the textbooks in science for Grades VII, VIII, and IX are likely to cause some reading difficulty for all but the better stu-

dents in these grades. The relative difficulty seems to be greatest in the textbooks for Grade VII. There is no evidence that the easiest portions of the textbooks are found toward the front of the books. The differences between the levels of difficulty of the easiest and the most difficult textbooks are statistically significant.

The same investigator (10) in a study of 26 biology textbooks found a wide variation in the reading difficulty, ranging from a level of Grade VI completed thru college completed. In view of the more common years of the study of biology in high school (Grades X and XI), serious problems of reading difficulty are likely to be encountered.

The extent of use and methods of use of teaching aids in biology textbooks were the concern of a study by St. Lawrence (19). Fourteen teaching aids were involved. Evaluations were provided by teachers. Generalizations derived from the study were: that determined by the extent of use, textbook teaching aids were not generally conceded by teachers to be of educational value; that textbook authors' reasons for the inclusion of these aids did not appear to have much relationship to the facts of use; that factors of teacher training, teaching experience and school size had little influence upon the extent of use and method of use of teaching aids. Major reasons indicated by teachers for not using textbook teaching aids were that they provided their own materials and that similar and more appropriate aids were otherwise available.

Business-Sponsored Materials for Science Teaching

Recent years have brought a major increase in the numbers and types of business-sponsored materials useful to science teaching. Available research reflects the concern of educators, as well as others, that the material be carefully prepared and effectively used.

One of the more significant research studies in this field was a survey by the National Science Teachers Association (15). This Association carried out an investigation of the use of materials in an effort to find the general basis of usefulness and the kind of use that materials have. A questionnaire was sent to schools using materials, and a statistically significant return received.

The questionnaire was concerned with 62 items which are classified principally as pamphlets. The titles of these items were given. There were 778 respondents to the questionnaire, of whom 246 had some responsibilities in teacher education. Of the 246, 28 work in teachers colleges. The 778 respondents reported 20 different ways in which they use the materials listed, such as classroom reference, special pupil reports, information for the teacher, etc. A table indicates the number of times each use is mentioned.

Twenty-six of the 62 items were evaluated in terms of the reading difficulty, interest level, reference to other publications, and certain other criteria. The items evaluated were distributed among those of greater and

those of lesser difficulty. The Flesch formula was used to determine the reading difficulty. This evaluation resulted in the following conclusions:

1. The 15 items voted lowest in special usefulness were on the average rated as more difficult to read.
2. The significant item that accounts for the difference in difficulty is the length of sentence. The items deemed highest in special usefulness were in general characterized by more sentences of shorter length.
3. The interest level of the reader is dependent upon the immediacy and current attention to the subjectmatter.
4. The popularity among teachers of an item seems to depend upon its "multiple use" in several science subjects.
5. The lack of a glossary has no significant effect upon the use of an item.
6. References to other publications are not essential for the special usefulness of an item.
7. The value of photographs versus diagrams requires further investigation.
8. The presence of photographs does not necessarily make an item easy to read.
9. There are more half-tone pictures in the items voted highest in special usefulness.

Among the conclusions reached in the study as a whole are the following:

1. Ninety-three percent of the respondents at all levels report business-sponsored teaching aids useful in broadening and deepening their own knowledge and understanding of science and technology in modern living.
2. Business-sponsored teaching aids are most widely used by teachers of the junior high-school grades. Ninety-seven percent report the materials useful to them personally.
3. Ninety percent of the respondents from the junior high schools report that business-sponsored teaching aids are useful to teachers and 83 percent of them report that business-sponsored teaching aids are useful to students.
4. Eighty-six percent of the college respondents report that business-sponsored teaching aids are useful to them personally and 78 percent report that business-sponsored teaching aids in the schools.
5. Educational authorities are overwhelmingly in favor of the use of business-sponsored teaching aids in the schools.

The "Report About Business-Sponsored Teaching Aids" by Sinclair (21) is concerned with problems and materials relating to the science area as well as to the other areas in education. The underlying purpose of this study was to discover the characteristic viewpoints of business representatives, classroom teachers, and school administrators on current practices in the production, distribution, and utilization of business-sponsored teaching aids.

The report indicates that data for this study were obtained from three principal sources: (a) Two hundred and eighty-nine classroom teachers

geographically distributed, representing all grade levels from one to 12 and representing the various subject areas in junior and senior high-school curriculums; (b) Three hundred and thirty-seven school administrators representing the various public school administrative positions; (c) Eighty-eight business organizations that sponsor free or inexpensive teaching materials.

The investigator used personal interviews and questionnaires to get data both from educators and from business representatives. Responses were obtained from 714 teachers, school administrators, and business representatives.

The major conclusions and recommendations are:

1. Educators favor for each state a single distribution agency to serve all business-sponsored teaching aids.
2. Descriptive lists of materials available from sponsors should be furnished by them, and materials should be provided to teachers and schools at no charge.
3. Materials should be prepared for use at specific grade levels, and by persons who know children and school needs.
4. Sponsored aids should be simple, easy to use and of a standard size and shape for filing.
5. While sponsors have put an emphasis upon materials such as booklets and charts, teachers prefer motion pictures and strip film when these are available.

The problem of improving the quality of brochures used in public schools was the subject of an investigation by Carriger, Lubold, and Govoni (4). Criteria related to pictorial materials, reading difficulty, current interest, and teaching aids were determined.

Investigations were based on commercially produced material. Positive correlations were found between the better liked brochures and matters of current public interest as revealed in the literature, and between the use of colored pictures and the desirability of their use.

Motion Pictures and Filmstrips in Science Teaching

Such projected materials as motion picture films and filmstrips have long been used by science teachers because of their promise in learning situations. The research, while of limited amount, has tended to support the use of these materials. Wise (23) studied the contributions of motion pictures as they supplemented other approaches to teaching. In five high schools, five biology films were shown to all sections except one in each school. The showings involved uniform methods of utilization, including preplanning by the teacher. Each film was used at the most appropriate time, and approximately two periods of class time were used during the study of each film. A 56-item test of multiple-choice type was constructed on the basis of the content of the five films. With an independent group the predicted reliability of the test was determined to be .64. Control groups, one class in each school, did not see the films

but spent the equivalent time used by the experimental groups in more complete utilization of other learning activities.

At the beginning of the semester the Film Test and the Cooperative Biology Test, Form P, were administered, and the same forms were given again at the end of the semester. It was concluded on the basis of the relations of the scores that the films must have contributed to student growth in two ways: as an equivalent substitute for other learning activities in the control groups, and as a means of presenting facts and concepts not taught by other methods. The use of a reasonable number of sound motion pictures closely related to the content in biology may materially enrich without detracting from normal student accomplishment.

The relative effectiveness of motion pictures, as compared with other materials, has been the subject of continuing concern among teachers. A comparison of motion pictures and equivalent teacher demonstrations was made by Smith (22). The investigator used three films, one each on magnetism, simple machines, and properties of water. The content of each was readily duplicated in the form of demonstrations by the classroom teachers. In each of five schools having three sections of general science the films were used, rotation of films serving to offset differences in teachers and students. Each section was eventually taught by each method on the successive units. Units were constructed to fit the content of the films. For a given topic in a given school one section was taught using the film and no demonstrations, a second with demonstrations and no film, and a third with both. Sections were rotated as to method for subsequent topics.

The California Test of Mental Maturity and a carefully prepared multiple choice test were used. The same tests were used before and after the experiment. The data were treated statistically. The investigator concluded that sound motion pictures and teacher demonstrations are equally successful in teaching, and that differences in intelligence have no bearing on the effectiveness of one method over the other.

A study of the narration in science films was carried out by Mallinson (9). Ten science films were used, five from biological science and five from physical science. These films were selected by the producers as being best at the junior high-school level. The investigator found 87 words of a difficulty level above Grade VII. He noted that more comprehensible words in the form of synonyms could have been used.

As a portion of his study on adjuncts to science instruction, Anderson (1) determined the availability of projectors in 56 of the 483 high schools in Minnesota. Projectors for motion pictures, filmstrips and lantern slides were available in the order given. He found that none was used fully. The criteria for full or optimum use no doubt were formulated in the investigation but were not indicated in the report.

An analysis of filmstrips in science to determine their inclusion of scientific principles, scientific method, and scientific attitudes was made by Royal (18). Two filmstrips were chosen for each of certain topics

in general science. A preliminary analysis of these filmstrips was made by the investigator to determine the scientific principles, methods, and attitudes. These results were submitted to two specialists for validation of the preliminary assignment by the investigator. The filmstrips were reanalyzed one year later by the investigator to determine the reliability.

It was concluded that of 1408 frames in the filmstrips only 574 made any contribution to scientific principles, methods, or attitudes. The major purpose of most filmstrips seemed to lie in their contribution to the topical organization of subjectmatter.

Graphic Materials

Science materials include such graphic materials as cross-sections and process diagrams. The degree of abstractness and subsequent difficulty of interpretation seems not to have been a matter of much concern to science teachers in the past, if the reports in the literature are a reliable index.

Two investigations by Malter indicate a certain awareness of potential difficulties in the use of graphic materials. In one study relating to ability to read cross-sections (12), 348 pupils in Grades IV to VIII were involved. It was determined that most of the pupils were unable to read many of the cross-sections appearing in their reading material. In another study involving 227 pupils in the same grades, they were asked to trace the flow of materials thru a process diagram of a flour mill (13). Most were unable to do so.

Materials for Experimentation

For many years there seemed to be a naive assumption that the primary purpose of the science laboratory was that of demonstrating and observing facts and phenomena already learned—to illustrate and show, but not to *experiment*. There seems to be a growing concern that the materials of the laboratory be used for genuine student investigation. This concern is reflected in research reported in the literature.

In a study made by Forbes (5) the following criteria for significant laboratory experiences were formulated:

1. A cooperatively planned group approach is in effect. The area under investigation is one with which the group identifies itself; one of importance to the people in the class.

2. The experience with concrete materials is introduced because of its potential contribution to current inquiry.

3. Materials are observed and manipulated with an understanding of their general position in the environment. In each experience there is an element familiar to the individual, related to part of his environment.

4. The procedure to be followed is determined by the group. This may involve much original planning, may be adapted from procedures found in publications, or may be suggested by the teacher. Of more

importance than the step-by-step details of the procedure are the reasons for the several details.

5. The several abilities and backgrounds in the group are utilized in the execution of the procedure and fruition of the experience.

6. Among the results, the focus of attention is on the ideas which are contributed by the experience to the association of ideas in which the problem or question occurred.

This problem was approached directly by Boeck (2) who compared thru experimental evaluation the learning of students taught in such a manner as to stress the use of the inductive approach in high-school chemistry laboratory exercises and correlated discussions with the learning of students who were taught by the use of the more commonly found deductive-descriptive exercises.

This study used experimental and control groups. An experimental and control group were selected from the junior and senior class students comprising the chemistry enrolment of the University of Minnesota High School by use of random sampling technics. Seven additional control groups were selected at random from Minnesota high schools of the same sized enrolment. Each of these control groups participated in the measurement of only one part of the total study. No attempt was made to control the type of teaching carried out in these schools. A survey was made of the nature of the teaching, materials covered, and the nature of the total teaching situation. This was accomplished thru a personal visit by the experimenter and the use of a questionnaire checklist. Enrolments in the various classes ranged from 19 to 30.

Measures were taken to evaluate such factors as mental ability and initial status. The examinations used in the study were validated prior to their use.

For the University High School experiment differences not large enough to be significant were found in favor of the inductive method for knowledge of facts and principles, application of principles, performance laboratory technics, and laboratory resourcefulness. However, for two objectives, differences in mean achievement were considered significant. They were (a) knowledge of and ability to use the scientific method with an accompanying scientific attitude and (b) identification of proper laboratory technics. Differences were in favor of the inductive group and the null hypotheses were rejected.

The findings from the retention examinations covering the applications and scientific method and attitude objectives showed differences in mean scores on the examinations in favor of the inductive group of about the same magnitude as those for the retest. These differences were not found to be significant. This was probably caused by the fact that the number of students involved in the retention examination groups were reduced to approximately one-half by graduation thereby requiring much larger differences for significance than were found because of a reduction in the number of degrees of freedom.

The analysis of the data resulting from the addition of control groups from out in the state indicated an advantage in favor of the class using the inductive method over one of the two classes using the deductive method for each of the objectives:

1. Acquisition of facts and principles of chemistry.
2. Ability to apply facts and principles to new situations.

The class using the inductive method was found superior to all three outside control classes using a deductive approach for the scientific method and attitude objective. All the above differences were significant at the 1 percent level.

The mean achievement of the University High School control group using the deductive method was superior (1 percent level of significance) to an outside control group with respect to acquisition of facts and principles and knowledge of and ability to use the scientific method with an accompanying scientific attitude. On the latter objective, the control group was superior to two outside control groups at the 5 percent level of significance.

A challenging and undeveloped phase of laboratory work, that in Grade IX general science, was the basis of a study by Sarris (20). His investigation was designed to determine the principles and experiments of biological and physical science found in four Grade IX textbooks of general science and the defensible assignment to these principles of the experiments, the performance of which should help pupils of Grade IX to develop an understanding of these principles.

Lists of principles developed by earlier workers in the field served as criteria for the relation of the laboratory work to the content of the textbooks.

In the four textbooks examined it was found that 62.71 percent of the principles were in physical science, 37.28 percent were in biological science. However, the experiments proposed were in an eight to one ratio in favor of the physical science. The investigator concluded that many of the experiments are useless and should be eliminated.

The qualities of demonstrations and apparatus involved have been studied at some length. Qualities of the apparatus used were the subject of a survey study by Mark (14).

The investigator attempted to bring together from the literature a composite of the statements of writers as to the desirable qualities in demonstration apparatus. The literature of a period of approximately 25 years was used. The quality of the literature cited varied from validated criteria to expressions of judgment of individuals. In preparing the checklist presented the author cites 27 references; the bibliography includes 22 books and 31 journal articles.

The investigation is of such nature as to lend itself with difficulty to statistical treatment. The effort to weight the various factors involved is commendable.

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CHAPTER IV

The Teaching of Mathematics in Grades I thru VIII

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Summaries and Bibliographies

In the period covered by this review a number of significant summaries, bibliographies, and compilations have appeared. Altho some of these include or refer to articles which are not primarily reports of research, they are included here because of their preeminent usefulness to workers in the field.

Fehr (32), Beatty (5), and Van Engen (95) summarized research in arithmetic and discussed implications of this research for the organization and learning of arithmetic. Beginning in December 1950, Kinsella (52) reported monthly a summary of research in mathematics. Subsequent issues of this journal continue this summary.

Wilson (102) made an extensive revision of an earlier research review. Moser, Kinney, and Purdy (64) surveyed the literature pertaining to the aims and purposes in the teaching of mathematics. Spitzer and Burch (81) reviewed the discussions in the literature which dealt with methods and materials.

Annual annotated bibliographies in arithmetic have been reported in each November issue of the *Elementary School Journal* by Hartung (46). A selected list of references on arithmetic was provided by Van Engen (92).

Compilations of Arithmetic Articles

Part Two of the *Fiftieth Yearbook of the National Society for the Study of Education* is the first yearbook devoted to arithmetic to be published in 10 years. Chapters in this yearbook which are not reported elsewhere include one by Horn (48) which outlines the place and relationship of arithmetic in the total curriculum of the elementary school and three by Swenson (89), Thiele (90), and Van Engen (94), which focus in turn on the arithmetic program in the primary grades, in the middle grades, and in the junior high school. Spitzer (78) wrote a chapter presenting various methods of teaching arithmetic and Buswell (19) examined the teaching of arithmetic in relation to presentday concepts of the psychology of learning. The final chapter is significant for future research because of Buswell's (18) identification of the changing concepts of research and because of the 21 projects for research which were proposed by as many different educators.

Two University of Chicago monographs (15, 17) reported papers read at the 1948 and 1949 conferences on arithmetic. In addition to papers

mentioned elsewhere, the 1949 monograph contains a discussion on the use of workbooks by Schneider (76) and another regarding the administration of the arithmetic program by Wingo (104). In the 1949 monograph, Morton (61) identified the place of arithmetic in various types of curriculums, Mott (65) discussed work in the primary grades, Wilburn (99) reported on experiments in self-instruction, Willcutt (100) cited classroom experiences involving pupil participation and Rogers (75) explained the idea of cooperative inservice arithmetic studies.

Studies Evaluating the Meaning Approach

The effect on learning, transfer of training, and retroactive inhibition of three methods of teaching addition facts to second-grade pupils was studied by Swenson (88). The three methods were the *generalization* method with pupil discovery of generalizations, the *drill method* requiring memorization, and the *drill-plus* method with facts organized by sums and use of concrete materials in introducing facts. Each of the 14 classes was subjected to two weeks of readiness preparation, five weeks of training on the first set of addition facts, five and a half weeks on the interpolated set of addition facts, and four weeks on the final set of addition facts. Tests on the facts were administered at five points. Three transfer tests were also given. Significantly higher scores were found for the *generalization* method on the original set of addition facts. This method had an advantage in overcoming retroactive inhibition and promoting transfer. In general, the conclusions are adequately based on the data obtained. However, the inference that organizing facts according to sums is a poor form of organization is open to question. Little attempt was made to utilize the inherent advantages of this organization.

In a study notable for its careful design and thoro execution, Brownell and Moser (10) determined the relative effect of a meaningful versus a mechanical approach when the decomposition method is taught and when the equal-addition method is taught. The study involved 1400 third-grade pupils in 41 schools. The criteria of success included not only measures of rate and accuracy, but also evidence pertaining to smoothness of performance, degree of understanding, extent of retention, competence in transferring to new skills, and the values which accrue when a crutch is used. The data provided by tests, interviews, and teachers' diaries revealed that: (a) decomposition taught meaningfully was the most successful method; (b) the equal addition method was difficult to rationalize; (c) when the teaching was mechanical, the equal addition method had some advantage; (d) the crutch was helpful when teaching the decomposition method and was discarded when teachers guided pupils away from it later; (e) pupils who had been taught meaningfully retained the learning longer and were better able to transfer this learning; and (f) the most economical route to speedy and accurate computation was thru the use of rational procedures. This study emphasized that

when methods are being compared, the extent of rationalization may well determine which method has the advantage.

To evaluate teaching which emphasized understanding and generalization (field theory) as contrasted to teaching which emphasized discreteness of elements of knowledge and skill (connectionist theory) Anderson (2) conducted an experiment which involved the year's work of fourth-grade classes in 18 schools. No specific prescription was made concerning objectives, content, or day-by-day procedures, but logs were kept by teachers and the differences in progress were found to be unimportant. The analysis of data from standardized tests indicated that neither method held a significant advantage in the learning of computation and problem solving. For the development of mathematical thinking as measured by a special test there was evidence that for pupils with below-average ability but above-average achievement, there was some advantage in the drill approach. The approach emphasizing understanding and generalization, however, seemed to be advantageous for those with a high level of ability but low achievement—and remedial pupils frequently are in this classification.

Howard (49) compared three methods of teaching fractions to 15 classes of children in Grades V and VI. These methods included: (a) a typical drill method, (b) a method which emphasized the "why" of each step with the practice incorporated in problems, and (c) a method comparable to (b) but which also provided computational practice like that in method (a). At the close of the 16-week teaching period, the advantage for one group resided in the drill approach but no one of the methods held an advantage for the other groups. However, a retention test in September indicated a high rate of loss for drill-trained pupils, a smaller loss for those who had been guided to understand, and for the pupils with both meaning and practice, there was very little loss. Some members of this last group actually had higher scores than in the spring testing.

Under Alkire's (1) direction, one class studied the meanings and relationships underlying the reciprocal technic when the divisor is a fraction while another class memorized the inversion rule and practiced its application. At the close of the teaching period the experimental group had a lower level of achievement than those who had memorized the rule. A retention test five months later indicated, however, that the experimental class had only slightly lower scores and that the group who had memorized a mechanical procedure suffered a high rate of loss. This study, tho small, provided another bit of evidence of a pattern that seems to be evolving from studies involving meanings: (a) at the end of experiments the approach which emphasizes understanding does not always seem to have an advantage over an approach involving only memorization of a mechanical procedure; (b) when retention is measured after a considerable time, the advantage of the meaning approach is revealed, for the learning seems to be more durable.

Discussions on Meaning

According to Hendrix (47) the child acquires a concept when a subverbal, organic, dynamic state of awareness has been achieved. Meaning, according to her, is learning the symbol which stands for the previously-achieved concept. Van Engen (93), in an erudite discussion of meaning, brought out the idea that meaning must come from having the child see action and perform the act himself prior to presentation of the symbol which represents the act. His analysis of meaning was focused on those meanings which are operational in nature rather than syntactical. Weaver (96) pointed out that sometimes it is better not to use representative materials of any kind in developing meanings. An overview of the modern arithmetic program which emphasizes meanings was presented by Burch (14). Stern (82) described a method she called Structural Arithmetic, which she believes is more consistent with the inner nature of number than are most of the concrete procedures which teachers use. The role of discovery in the meaningful program was outlined by McSwain (59).

Johnson (51) argued that pupils need to know the process steps before they are presented with the rationale. He listed three types of meanings: (a) structural meanings, (b) functional meanings, and (c) rationalization of processes.

Fawcett (30) listed number, measurement, relationship, proof, operation, and symbolism as concepts which unify mathematics and which grow in meaning and significance as mathematics is studied.

Wheat (98) dealt with the nature of learning activities in arithmetic and their sequence as determined by the relationships which are inherent in a decimal number system.

A presentation of several fundamental issues in the teaching of arithmetic was made by Clark (22). In order to bring more light to bear on the important issue of how to redistribute class time so as to provide a better balanced program of meanings and drill, Hartung (45) called for cooperative research, local tryouts of various time allotments, and more careful over-all planning by individual teachers.

Mental arithmetic, in Boulware's (8) research, involved using the nature of the number system as a basis for performing arithmetic processes. His study traced the development of mental arithmetic and defined its place and value in the modern program.

The Social Aspects of Arithmetic

Buckingham (12) examined the contributions of social institutions and arithmetic to each other and related these contributions to the presentday program. Brueckner (11) cited the social contributions that can be made by arithmetic.

Two studies were concerned with social units as the context within which arithmetic was taught. Five units were used by Passehl (70) as the source of the arithmetic content for teaching the four fundamental opera-

tions with decimal fractions as well as the multiplication and division of common fractions. An average of 79 percent of the class mastered at least three-fourths of the steps. Williams (101) used an experience curriculum with nine successive sixth-grade groups. The pupils had average gains of over a year when compared with norms for standardized tests. The investigator reported other values which accrued thru use of this kind of program.

The functional-use theory was stressed by Harding (43) as more consistent with organic processes that involve the whole person in his environment than is the drill approach or the meaning approach.

Arithmetic Textbooks

Eckert (29) analyzed multiplication of fractions in nine textbook series and proposed a program to overcome the inadequacies which were revealed. After analyzing 10 series of textbooks Conrad (23) found that ambiguities in wordage, discrepancies in fact, inconsistencies, and incomplete source materials accounted for 65 percent of the sources of errors and confusion. Dreier (28) noted that less than 10 percent of the pictures and less than 4 percent of the problems in six third-grade textbooks had a rural setting.

Thru a comparative analysis of older and more recent arithmetic textbooks Boynton (9) presented objective evidence to show that recent textbooks provide (a) a greater use of the group idea for number, (b) a more systematic use of component parts, (c) a slight improvement in the use of the ratio idea, (d) a more frequent use of the series idea in multiplication, and (e) a more extensive utilization of tables for discovery of relationships.

By observational technics and questionnaires, Hamilton (42) studied the usage of arithmetic textbooks in 50 elementary classrooms. She found that 86 percent of the teachers followed textbook procedure and that these teachers consistently preferred the "best theory method" of teaching arithmetic—a theory which represented a compilation of the best features of methods as set forth in the literature on teaching arithmetic.

Readiness

The number of experiences confronting 12 three-year-old children were observed by Clark (21) during morning school sessions for four weeks. Terms of position and indefinite comparison were best understood, and these seemed usually to occur in relation to the child himself. Considerable confusion existed in reference to counting, time, pupil age, and number concepts of 2 and 3. MacLatchy (58) described various technics she had designed to be used in determining the familiarity of preschool children with measurement.

To determine the relative achievement in arithmetic of kindergarten pupils who were subjected to a planned program of number experiences

with matched pupils who did not have such a program, Koenker (53) used two kindergartens which had double sessions. Each teacher used one of her groups for an experimental section and the other for a control section so the quality of teaching as a variable was better controlled than is usually the case. When tested in May, the 27 experimental pupils had a mean score of 23.44 (a gain of 10.22) and the control pupils had a mean score of 18.74 (a gain of 5.15). Six of the pupils who had the planned arithmetic program held an advantage of 10 or more score points over their respective matches in the control group. In another publication, Koenker (54) reviewed the research relative to the value of a systematic program for primary-grade children and proposed a program for kindergarten and Grade I.

Beltramo (6) identified nine skills which are important in the process of counting and then listed poems and stories which are useful in teaching these various skills.

The value of meaningful number experiences in promoting arithmetic readiness was discussed by Moser (62).

The Process of Division

Two discussions of division with two-figure divisors favored the apparent method of estimating the quotient figure over the increase-by-one method. Moser (63) found that college freshmen using the apparent method were just as accurate as those who utilized the increase-by-one method. Then, using the problems of teaching rather than statistical analysis as his basis, he presented cogent arguments which led to the conclusion that the apparent method was a better approach for children who are learning to estimate quotient figures. Osburn (69) utilized a statistical approach which took advantage of the fact that the data could be ranged in a dichotomized classification. His analysis revealed clearly that frequently the increase procedure was unnecessary and was sometimes harmful. Thus, the increase-by-one method was found to have less of a statistical advantage than has been reported in some analyses.

Fuller's (33) control group used the increase-by-one procedure for finding quotient figures while the experimental pupils were required to work out a table of multiples of the divisor to nine times the divisor, as a source for quotient figures. Differences favoring this experimental approach were found in his final experiment but these differences were not significant. The pupils, however, liked the table approach and understood it quickly altho they were slower than the pupils who used the increase-by-one procedure.

Smith (77) illustrated what could be done at each grade level, beginning with Grade I, in order to build carefully the concepts and relationships that are needed for understanding the process of division.

Step-by-step spiral development in division was shown on a chart by Gates (34) to illustrate her discussion of the use of this plan of organizing arithmetic work.

Problem Solving

Cronbach (24) discussed various suggestions for the problem-solving program in arithmetic and noted the psychological difficulties that are likely to be encountered.

Thru testing and oral interviewing, Burch (13) evaluated problem tests which require pupils to respond to analytical steps (What is given? What is to be found? What is the estimated answer? How is the problem to be solved?) prior actually to solving each problem. He found that the pupils tended to score higher in problem-solving in the test that did not require response to the analytic steps and that even when pupils had been taught to use the steps, they did not do so except under compulsion. Welch (97) obtained data which indicated that problems expressing social situations in life were not solved with any greater success than were "unreal" problems, and that pupils actually tended to prefer the problems which were unrelated to life situations. Sutherland (87), after analyzing 15,000 verbal problems, discovered four basic thought patterns requiring the process of addition, 10 involving subtraction, eight for multiplication, and 16 for division. Hartung (44) discussed progress in the teaching of problem-solving.

Evaluation

Peters (71), tracing in detail the development of evaluation in arithmetic noted that after 1930 testing instruments became more inclusive. Evaluation procedures, according to her, are still far behind recognized needs which have been pointed out in discussion of authorities.

In constructively criticizing presentday testing, Spitzer (79) indicated that tests too often have the same form and language as that used in instruction, and that they overemphasize exact computation. He then suggested several excellent variations to use in evaluating pupil progress. In another article Spitzer (80) surveyed presentday testing instruments and practices and then made 10 suggestions for improvement. Glennon (36), as a prelude to a report of a study which used a test designed to measure understanding cited six reasons why tests of meaningful content have been slow in developing. A detailed presentation of evaluation in arithmetic was made by Sueltz (84) and illustrations of newer methods of testing were provided. Storm (83) presented an extensive list of meanings which he felt should be tested.

Buswell (16) suggested that evaluation of pupils' thought processes provides needed insight into the extent to which these pupils understand the concepts and procedures. He described six methods for obtaining evidence of pupils' thought procedures.

Multisensory Aids

Grossnickle (38) was responsible for an earlier over-all view of multisensory aids and, somewhat later, he and Metzner (40) wrote a three-

chapter volume in which they discussed (a) the place of visual aids in a meaningful program in arithmetic, (b) ways in which this kind of aid can be used, and (c) sources from which audio-visual aids may be obtained. Grossnickle also joined with Junge and Metzner (39) to produce an extensive and useful chapter concerned with instructional materials and manipulative aids.

Motyka (66) provided a review of learning aids and Lazar (55) presented in detail the use of a device for teaching concepts and operations relating to integers and fractions.

Individual Differences

Ramharter and Johnson (73) found that high achievers were superior to low achievers in accuracy, correcting errors quickly, retention, and study technics.

Grime (37) in discussing the 14 level division of the Cleveland primary-grades course of study in arithmetic, indicated the various ways in which such a program makes provision for individual differences in the teaching of arithmetic.

By matching a group of mentally retarded children with a group who were chronologically younger but had the same mental ages, Cruickshank (25) was able to isolate variations in ability for these two groups. He found that when problems had extraneous material and when the problems had no numbers, the mentally retarded pupils were much more confused than the normal pupils with like mental ages.

The number abilities of bilingual Mexican-American children in Grade I was found by Rhue (74) to be inferior to those of children of a comparable Anglo-American group. A study by Plank (72), while relatively unsystematic, suggests possibilities for research dealing with factors in personality structure and mathematics background that lead to failure. MacLatchy (57) found that creative thinking may actually lead to errors.

Preferences of Children

Chase (20) reported a large scale study of subject preferences of 13,383 fifth-grade children in New England, and 2350 fifth-grade children in a southwestern city. This study revealed that reading and arithmetic were the two leading subjects in children's preferences, and that arithmetic was the very definite preference of the teachers.

In Dean's (26) study, the children with higher achievement in arithmetic tend to list arithmetic as their first preference and those who prefer arithmetic tend to have a higher level of achievement in arithmetic.

Miscellaneous

Fay (31) determined abilities of sixth-grade pupils in certain specific reading skills. When chronological and mental ages were controlled, he found that those who were superior in the reading skills had no higher achievement in arithmetic than those who were inferior.

Bernadetta (7) discussed a four-point plan which she felt was important in connection with the completion of any unit in arithmetic.

In order to study the possibility of predicting future arithmetic achievement from measurement of pupil performance in Grade I, Olander and others (68) constructed two arithmetic scales. The first measured quantitative information and the second evaluated the ability of pupils to perceive relationship. Three years after administering the arithmetic scales, 289 of the pupils who took the first-grade arithmetic tests were again tested. When the evaluations of the first-grade tests were correlated with the problem-solving section of the Unit Scale of Attainment, a correlation of .55 was obtained. The correlation for fundamental operations was .51. This extent of correlation with arithmetic provides an efficiency of prediction of about 15 percent over prediction by guessing.

In order to determine whether teachers' judgments agree with research and expert opinion, LeBaron (56) had 22 teachers respond to a questionnaire containing 72 declarative statements taken from research or authoritative sources. On the average there was about 50 percent agreement between teachers' opinion and the statements that were included in the study. Glennon (35) reported on a program of cooperative research which was carried out by supervisors and teachers in the central section of New York state. Trimble (91) illustrated ways in which the concept of the fraction as a ratio may be developed concretely so that real meaning is attained.

Mathematics in Grades VII and VIII

Interest of researchers at the junior high-school level traditionally has been preoccupied with discovering and analyzing computational deficiencies of pupils. Research studies reported for the three-year period ending April 1, 1951 follow the same general pattern but with a difference. The studies currently reported are concerned as much with meanings, judgments, and functional applications of arithmetic as with the purely computational aspects. Undoubtedly this broader frame of reference reflects in part the spirit and influence of such writings as the "Second Report of the Commission on Post-War Plans" (67).

Arthur (3) prepared a test to see which of the essentials proposed by the Committee on Essential Mathematics for Minimum Army Needs (1943) required further attention in high school. He found that freshmen entering high school three and four years after the publication of the report did not have adequate understanding of, or the ability to work many of the problems considered essential. Much specificity in learning was revealed by the test. Important difficulties with decimals and percents were also found. Arthur concluded that remedial teaching at the high-school level is necessary to meet the essentials listed by the committee.

A study by Montgomery (60) supplements nicely the findings of Arthur. Montgomery investigated the ability of seventh-grade pupils to use decimals, fractions, and percents interchangeably and with understanding.

The scope of the problem was confined to "Case II" relationships. A special test was designed to measure the degree of understanding as well as facility in abstract computation. These tests were given to 624 pupils in Grade VII. Results showed that children could not use all three forms with equal facility. Comparisons yielding values greater than unity, or 100 percent, were especially troublesome.

When the population was divided into high, middle, and low thirds it was found that the high third could use all three forms with about equal ease. The middle third could use common fractions with more facility than either of the other forms, and the common fraction form was much preferred by pupils in the lowest third.

Montgomery pointed out the need for reducing specificity in learning by a more meaningful approach to the interrelationships between decimals, fractions and percents. Much more attention needs to be given to fractions as ratios. He also pointed out the inadequacy of current test instruments for measuring these interrelationships.

Sueltz and Benedick (86) called attention to the fact that the capacity to use arithmetic functionally means more than ability to compute. They constructed a test to measure understandings and judgments as well as computation and problem-solving. The results from testing 2000 sixth-graders in three eastern states revealed glaring weaknesses in all four areas. The tests were repeated in Grade IX and in the senior high school with approximately the same conclusions. The authors found that competence in functional arithmetic falls beyond the sixth-grade level. Furthermore, the present program of mathematics at the junior and senior high-school levels is not adequate to overcome the shortcomings and deficiencies revealed by the tests in Grade VI. The secondary schools should spend less time redoing or improving the work of the elementary schools and make arithmetic an integral part of their program.

Glennon (36) reported pioneer research with an instrument for measuring growth in understandings and meanings in arithmetic. He constructed a multiple choice test of 80 items covering five areas of meanings and understandings basic to the computational processes taught in Grades I thru VI. The test was validated in part on the basis of combined judgments of 16 experts in subjectmatter and in part by observations of its ability to distinguish between pupils who understood the meanings and those who did not. The test was administered to 1139 subjects at seven levels: Grades VII, VIII, IX, XII, teachers-college freshmen, college seniors and inservice teachers.

No significant difference in achievement of basic mathematical understandings between seventh- and eighth-graders was found. Ninth-graders, however, were found to be significantly superior to eighth-graders. One may question the educational significance of this difference without challenging the statistical conclusion. The mean score in percent of items correct was 14.01 for Grade VIII and 18.02 for Grade IX. In an 80-item test the difference in means would amount to 3.2 items which is hardly

an educational accomplishment of any magnitude to show for one additional year of work. According to Glennon, the test revealed the meager degree with which teachers are succeeding in bringing about meanings and understandings.

Taken together, the studies of Arthur, Montgomery, Glennon, and Sueltz and Benedick seem to indicate an amazing sterility in mathematical accomplishment at Grade VII and Grade VIII levels. A reexamination of content and reevaluation of procedures for correcting these deficiencies is called for.

Sueltz (85) raised important questions concerning the use of research in curriculum construction. The following are of general interest: Is it possible to test and evaluate all the important goals in arithmetic? Can the results of piece-meal researches be summarized into a large or total pattern? Is current research thoroly reliable, or do method, point of view and incentives limit research results to the original experiment?

Johnson (50) reported a study in which he attempted to identify some of the intellectual factors most closely related to the ability to solve verbal problems in arithmetic. His study, made at the eighth-grade level, found the greatest relationship between problem-solving and general vocabulary. The correlation ratios obtained ranged from .45 to .51. The factor showing the second closest relationship to problem-solving was reasoning (.37 to .47). A surprising discovery revealed that when problem scales without numbers were used in place of the regular problem scales the order of relationship was reversed, i.e., correlation ratios for reasoning were higher than the correlations with vocabulary.

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CHAPTER V

The Teaching of Mathematics in High School and College

LUCIEN B. KINNEY, EDWIN EAGLE, and CHARLES PURDY

GENERAL trends in secondary mathematics over the 30-year period from 1918 to 1948 were studied by Wilson (55). He utilized, as his sources, statements of authorities, textbooks, research publications, reports of national committees, and courses of study. He noted trends toward (a) the teaching of meaning and understanding, (b) effective guidance of pupils, (c) increased use of audio-visual aids, (d) greater use of enrichment materials, (e) efforts in many places to organize mathematics effectively and functionally for general education, and (f) attempts to desire and use more critical methods of evaluating the outcomes of instruction and achievement of the learner. This agrees in general with the summary of Schaaf (47) and the Report of the Trends Committee of the Central Association of Science and Mathematics Teachers (24, 25). Research in the field during the period covered in the present report follows rather closely the same lines of emphasis.

Analysis and Formulation of Aims

Studies of aims in mathematics have utilized three approaches: appeal to authority and practice, life needs, and philosophy of education.

Studies of life needs have recognized both the nature of the child and the life situations where number is involved. Kinsella (28) pointed out the characteristics of the adolescent that must be recognized in an instructional program in arithmetic. Several have been in line with the plea of Betz (6) for a complete study of the role of mathematics in the modern world. The contributions of mathematics to general education were analyzed by Breslich (8), Rosskopf (44), Sturm (51), and Gager (16) in order to trace the background of the present general mathematics program and enunciate purposes such as development of the ability to recognize and use quantitative data in the study of social problems, to prepare for citizenship, to develop an appreciation of cultural values, and to meet the daily mathematical needs.

In a more specific curriculum, Kinney (27) examined the evolution of the mathematics curriculum at the New York State Maritime College in terms of the needs of workers in the marine field and made recommendations for a continuing program of improvement. Other studies of this general nature that were parts of more extensive projects in curriculum construction are cited in a later section of the present report.

Various technics have been utilized to formulate aims based on opinions of authorities. Brown (11) polled 700 teachers of secondary

geometry to determine the objectives that they held most important. Objectives held most important by students were found by visiting "a few" classrooms and questioning pupils as to purposes. These responses were tabulated and were compared to the textbooks in use. The most important teacher objectives were to develop the habit of clear thinking and precise expression and to give a knowledge of the facts and principles of geometry. The second teacher objective was rated highest by the pupils and the principal teacher objective was not included among the five most prevalent pupil selections. Hlavaty (19) evaluated Grade X mathematics, and 18 current textbooks on the basis of recommendations of national bodies in the field of general education, mathematical instruction, and the teaching of geometry. It was concluded that traditional demonstrative geometry instruction is still prevalent and that it cannot be rationalized in terms of the recommendations. Purdy (41) formulated, on the basis of authority, and validated by means of validation criteria, a set of aims for an experimental course in college general mathematics, and then determined the degree of achievement of those aims in a particular course.

Ibrahim (20) examined philosophies of education for the implications for mathematics curriculum and classroom procedures and contrasted the different philosophies with schools of psychology. He emerged with a preference for pragmatism as a philosophy and organismic psychology.

Content

Wilson (55) pointed out the shifts in content over 30 years in elementary arithmetic, algebra, plane geometry, and general and social mathematics as reflected in textbooks, courses of study, proposals by authorities, research, and committee reports. A few of the shifts identified in that study were to mathematical and social arithmetic, more informational material, fresh applications spaced to maintain skill, organization by units or chapters, large emphasis on applications, use of nongeometric materials in geometry courses, and exercises for development of meanings of mathematical topics.

Current studies have utilized two approaches to improved content—the mathematical meanings needed for understanding, including the rationale of facts and processes; and the specific needs of life activities.

Needed meanings have been analyzed by Van Engen (54) who listed the understandings essential for the ready use of the language of mathematics to be acquired in the junior-senior high school and described methods for their development, and by Fawcett (13) who listed number, measurement, relationship, proof, operation, and symbolism as the "threads by which the program is unified and thru which it is related to other areas of learning." Fawcett subdivided each of his topics into appropriate mathematical skills and understandings.

Gager (16) reported a study of life needs to identify the concepts

that should be taught in Grades VII thru XII, as reported by a group of Florida mathematics teachers. These were used as the basis for a "second track" parallel to college preparatory mathematics.

A number of studies have been concerned with the mathematics needed for the study of science. Rich (42) investigated the place of functionality in secondary-school mathematics and the correlation of mathematical and scientific instruction thru functionality. He identified the keys to variable change and functionality as ratios, differences, rates of change, and two-set equations, and traced the application of variation, sense change, rate of change, and power variation to problem-solving. The *Twentieth Yearbook of the National Council of Teachers of Mathematics* (38) presented a comprehensive treatment of uses of the metric system in four main sections: (a) System of Measures—the need, scientific development, and widespread adoption; (b) The System at Work—evaluations and endorsements by users in varied fields of activity; (c) Of Public Interest—publicity given to the metric system thru press, radio, and groups advocating adoption, and (d) Toward Wider Use—methods of making the change both in general use and in education.

Wilson, Carpenter, and Nihard (56) reported the result of an analysis of mathematical needs for skilled trades prepared by the Los Angeles Supervisor of Apprentice Education to determine the kind and extent of mathematics needed by each trade. Sixteen mathematical units including whole numbers, common fractions, decimals, percent, linear measure, geometric rules, tables, graphs, formulas, solving equations for the unknown, slide rule, and trigonometry were identified. All of the 15 trades studied, excepting meat cutting, needed the first 13 units. Electricians, machinists, die makers, pipefitters, and refrigeration mechanics checked the last three also. This report also included a one-page outline showing more specifically the needs of each of the 15 trades in each of these mathematics units. Loflin (33) determined the mathematical facts, formulas, principles, and operations used in undergraduate courses in Chemical Engineering. This study was based upon descriptions of the courses recommended by the American Institute of Chemical Engineers, the catalogs of accredited institutions and the textbooks and periodicals in the field. It was found that many of the topics in the traditional courses of algebra, analytic geometry, trigonometry, and the calculus had no application to Chemical Engineering. This study showed that "only the simplest type of mathematical problems appeared in the applications." Among needs identified for chemical engineers were simple partial fractions, integrals chiefly of the forms $u^n du$ and $\frac{du}{u}$, problem-solving technics, and ability to set up fundamental equations.

Anderson (1) outlined the topics in which applications from aerial navigation may be used to enrich a course of study in junior and senior high-school mathematics, providing a body of professionalized subject-

matter for mathematics classes. This study covered spherical properties of the earth, geometry of position, celestial navigation, measurement and computation with approximate numbers, scale drawings, trigonometry, and functional relations of navigation as they apply to topics proposed by the Joint Commission. Kramer (30) gave the mathematical prerequisites necessary for meteorology, defined a program of mathematics for training meteorologists, and determined implications and source material from meteorology for use by mathematics teachers. This information was gathered by analysis of publications, papers, and curriculums at various schools.

Technics of Teaching

An interesting group of studies have been carried out to determine the comparative effectiveness of classroom practices. Results, in general, were inconclusive.

Michael (36) found no outstanding difference in student gain dependent on teaching technic in comparing an inductive approach with an authoritative, for teaching of signed numbers in Grade IX algebra. Gains in computation skill and generalization ability, and also attitudes toward mathematics, were evaluated for classes with similar prior mathematical instruction and for three ability levels within these classes. Slight differences were noted but none that were significant. In comparison of a technic involving a large measure of individual instruction, student participation, and functionality, with a conventional method in Grade IX algebra classes, Schultz and Ohlsen (48) found significantly greater gains with the individualized instruction in performance as shown by Ohlsen's Test of Mathematics Essentials for the Ordinary Citizen, and in pupil attitudes. Gains in algebra competence, however, were not significantly different. Lewis (32) found a statistically significant difference in critical thinking gain between an experimental group in plane demonstrative geometry and control groups receiving conventional instruction; technics with the experimental group emphasized fundamental concepts of methods employed and applications to nonmathematical situations. Better pupil attitudes and wide functionality were claimed for the experimental course but the amount of geometry learned was not significantly different from that of a comparable control group. In a similar situation involving a smaller divergence of technics, Lueck (34) reported a slight gain in the solving of "word problems" in algebra when emphasis was given to fundamental concepts, along with better pupil response and attitudes.

Purdy (41) undertook to formulate a course in general college mathematics for students who present not more than two years of high-school mathematics credit on admission. They were taking the course either as terminal mathematics, or as preparatory to further work in mathematics. Course activities were designed to impart understanding of essential basic concepts, familiarity with functional topics in mathe-

matics and desirable attitudes, and were carefully evaluated as to effectiveness in each area. Computational and manipulative objectives were achieved and simple vocabulary, symbolism, and concepts were mastered. Other areas showed gains but fell short of desired objectives. Response was irregular in abstract topics. Attitudes varied with degree of mastery attained but were generally satisfactory.

Furst (15) examined two groups of highly selected eleventh- and twelfth-grade students under contrasting curriculums to determine terminal ability to relate various reactions in adjusting to or solving problems. One group pursued a program of study in a conventional curriculum while in the other group objectives were primarily emphasized and "radically different" methods of instruction were employed. Conclusions were drawn from analyses of initial and final test data covering 27 areas of learning, of which four were mathematical. He found that both groups tended to organize their learning on a subjectmatter basis in much the same form of organization as the learning experiences had been presented and that there was little consistency in achievement outcomes from a given type of activity among the various subject fields.

Johnson (22, 23) examined the effectiveness of films and filmstrips in teaching plane geometry. Selectivity, both in the visual aids employed and the participating groups, was avoided. He found for one instructional unit that use of both films and filmstrips resulted in additional gains statistically significant. Used alone, filmstrips were judged to be superior to films. No conclusive advantage over conventional instruction was demonstrated and in one item tested conventional instruction appeared superior. Johnson and Syer (21) have compiled an extensive bibliography of films and filmstrips intended for use at the high-school level and listed them by subject and appropriate grade.

Sueltz (52) studied the retention by college freshmen of their mathematical understanding and judgment. Scores on the tests were compared to those of junior high-school pupils on the same test.

He concluded that: (a) pupils at all levels tended to learn those things that the teachers expected of them and to learn in a pattern set by the teacher; (b) weaknesses tended to persist from one level to another, particularly arithmetic learnings; (c) certain types of exercises in which the mathematical element was not complicated and which were found in situations where older students had experience proved easier for the older group; (d) the extension of learnings in arithmetic was neglected in the typical secondary-school program; (e) schools tended to place too much dependence on "paper and pencil" work; (f) confusion concerning the purpose of study and the values to be derived from the study of demonstrative geometry persisted in the minds of the students. In the recognition of geometric figures and concepts and in the application of many geometric principles, those students, who studied the informal and experimental type of geometry found in many junior high schools, tended to do as well as many students who spent

a whole year at demonstrative geometry; and, (g) students tended to do comparatively well in abstract manipulative algebra but tended to be too little concerned with understanding the significance of what they were doing.

Guidance, Diagnosis, and Remedial Instruction

The importance of counseling in the secondary mathematics program is generally recognized. A survey by Sanford (45) emphasized the need for more counseling. He found that, in the state of Illinois, most pupils enrol in science and mathematics courses in Grades IX and X but relatively few continued thru Grades XI and XII. Increased cooperation of other teachers, pupils, and laymen was proposed to meet more adequately the mathematical needs of youth and society. Among devices that may be used to create greater interest in secondary mathematics are scholarships or contests similar to the Westinghouse Science Talent Search. Mayor (35) determined what mathematics contests were held and what scholarships given in the different states, by polling state representatives of the National Council of Teachers of Mathematics. He found that little use was made of these devices for creating interest, altho opinion favored their use. The need for counseling was substantiated by Kinzer and Kinzer (29) who found that students who ranked low on an arithmetic problem test obtained low grades in college chemistry. Those who accepted remedial instruction in arithmetic were given a second arithmetic test. This group did satisfactory work in chemistry and their outcomes in chemistry were better predicted by the second test.

The quest for improved methods of predicting success in mathematics has continued to attract a number of investigations. Rosilda (43) studied the relation between IQ and scores on a first year algebra test for 635 ninth-grade pupils, finding a correlation coefficient of .42. Bromley and Carter (9) found that scores on college entrance tests did not correlate highly with average college mathematics grades. Their correlation coefficients ranged from .11 on the Silent Reading Ability Test to .35 on the Cooperative General Achievement Test score; rank in high school correlated .40 with college mathematics grades. Frederiksen (14) constructed a grade prediction graph for the courses in Algebra and Trigonometry, and Elementary Calculus at Princeton University. This graph was based upon a variety of factors, including the Cooperative-Survey Test verbal and mathematical factors, converted school grades, number of terms of mathematics previously studied, age and year of high-school graduation, level of comprehension score, and veteran status. It was found to have a predictive value within one grade range.

Study of methods for identifying causes of mathematical difficulties and remedial procedures continue to hold an important position in educational research. Arthur (3) devised a test to identify specific difficulties in the fundamental processes and problem solving in arithmetic.

The test was administered to about 200 freshmen in each of two years. He found a large proportion of high-school students incompetent in arithmetic, but that high-school courses typically do not provide for correction of these deficiencies. He recommended that remedial teaching be carried on in all high-school classes. Cruickshank (12) compared the ability of retarded children of a given mental age with normal children of the same age in ability to solve verbal problems. He found that the presence of extraneous materials in problem situations caused confusion to both groups, but the confusion was much greater in the retarded groups. Northrup, Pingry, and Winsor (39) made a functional item analysis of responses to items of the Cornell Mathematics Test, taken by 416 freshmen. The errors were tabulated according to classified groups of test items, to locate the groups in need of remedial help. They found that this analysis provided the teacher with an effective basis for remedial instruction. Bloom and Broder (7) investigated the differences in procedures of students in solving problems. Five categories of difficulties were identified and remedial programs devised. The students who were given assistance made significant gains over control groups of comparable ability. Gibney (17) appraised the value on grades in geometry from sectioning classes on the basis of aptitude tests. Students of lower aptitude were provided with much visual material and construction activities. Failures were considerably reduced and student interest increased. Habel (18) studied the extent to which a course in algebra and a course in general mathematics prepared students for success in dealing with percentage and also with fractions and radicals necessary for trigonometry. Initial and final tests were given in one semester courses in algebra and general mathematics. Neither course prepared students adequately for trigonometry. The need for additional remedial teaching in trigonometry was evident. Archer (2) designed and evaluated a procedure for teaching plane geometry effectively to mentally, physically, and emotionally handicapped pupils. A laboratory method was devised with extensive use of models and student activity. Twice as much time was used as in regular classes. Tension of the pupils was greatly lessened and achievement was very satisfactory. Berger (5) surveyed 500 colleges by questionnaire to determine the provisions being made for students poorly prepared in algebra. Eighty-five percent of those responding considered that freshmen are not prepared for college algebra. Methods to reduce failures included placement tests, homogeneous grouping, individual help outside of class and an elementary noncredit course. Such courses were found in half of the schools responding.

Testing Technics

A relatively small number of studies were directed to investigation of testing procedures and their effectiveness. Sears (49) reviewed the development of aims, content and structure of algebra tests since 1917,

when the first was published by Clark. Factors that have brought about changes were (a) course modifications, (b) new methods and materials, (c) refinement of technics for test construction, (d) changing objectives, and (e) the emerging concept of evaluation. The author concluded that a new concept of evaluation, in keeping with the psychology of learning which considers the growth of the individual as a whole, will have to be formulated. The presentation of evidence supporting this theory was the over-all idea of this study. In keeping with this new concept of evaluation she concluded that present practice in testing seems to be defining a more comprehensive evaluation of ability in algebra as that which includes the evaluation of personality traits as well as the evaluation of achievement in subjectmatter.

Michaelis (37) reviewed current practices in evaluation used in city school systems thruout the country. He concluded that, among the outcomes least adequately evaluated, were: democratic behavior, critical thinking, group processes, and social understanding of attitudes.

Kenney (26) examined a sample of 22 group intelligence tests for mathematical content. His findings led to the conclusion that "at least one of the abilities constituting intelligence is that of handling mathematical materials of various kinds." The percentage in individual tests ranged from 1 percent to 56 percent of the test.

Plumlee (40) undertook to determine whether verbal and nonverbal tests of mathematical ability measured the same factors, and whether there is a higher degree of relationship between verbal aptitude and verbal mathematics than between nonverbal aptitude and nonverbal mathematics. He found the measures of nonverbal mathematics more reliable than those of verbal mathematics. Differences in the measured abilities were not closely related to differences in verbal aptitude.

Teacher Preparation

Study of teacher preparation reveals a wide diversity between present status and desired preparation. Wilson (55) stated that "there have been many complaints in recent years that the training of the mathematics teacher is unsatisfactory in the light of present conditions in the high schools." That study produced evidence to support the following courses and experiences in preservice training of secondary mathematics teachers: statistics, applied mathematics, mathematics of finance, history of mathematics, field work in mathematics, audio-visual aids, and social problems.

Layton (31) investigated the rules and regulations on certification of mathematics teachers in the 48 states and the District of Columbia. Requirements from the office in charge of certification in each state were analyzed for professional and mathematics requirements and contrasted with requirements in English, art, and geography. Opinions on mathematics course work deemed necessary for mathematics teachers on different levels, minimum grade, and recommendations from colleges were obtained by questionnaire from certification officers in the states.

He found that requirements in mathematics for certificates for lower elementary grades had a nationwide mean in semester hours of .52 for content and .16 for method. This was considerably lower than corresponding preparation for English, geography, or art, while the mean professional requirement for this certificate was 13.01 semester hours. Very few states required any mathematics content or methods for the lower grades and only 11 states required mathematics content for upper grades. For secondary mathematics teaching credentials, all states require professional content, but there is little agreement on specific courses. About 30 percent of the states required no mathematics content courses. The range of content courses required was from zero to 24 semester hours, with a mean of about 10 semester hours. Only five states specified particular content courses for the secondary credential, with "little consistency among them." Only one state required study in related fields. The total number of mathematics hours required was less than the number for English teachers.

Ayre (4) studied the training, experience, teaching load, course offerings, class size, and salaries for junior college mathematics teachers in eight central states. He found that all of the 100 teachers held bachelor's degrees, 91 percent held masters degrees, and 3 percent held the doctorate. Mathematics was the major subject for 70 percent of the undergraduate degrees, 55 percent of the masters degrees, and all of the doctors degrees. Twenty-four percent did major study in education and only 5 percent in mathematics education. Mean semester hours of study in the various areas were: undergraduate mathematics 27.2, graduate mathematics 21.0, related areas 14.0, and mathematics education 6.3. Teachers in general indicated that their graduate and undergraduate training was adequate in all respects, but to the question, "How could it have been improved?" 40 percent replied more mathematics, 60 percent more work in related areas, 8 percent more education courses, and 27 percent more mathematics education. The mean number of periods taught per week was 17 with a range from four to 33. Class size ranged from two to 42 with 20 the average. Salary ranged from $2325 to $5645 with the median $3600 and mean $3500.

Studies directed to improvement of teacher preparation have utilized the survey of opinion, and experimentation.

Thacker and Read (53) polled 263 high-school mathematics teachers, 107 heads of college mathematics departments, and 83 heads of college education departments in the middle west to find the college courses they considered desirable in training secondary mathematics teachers. A high degree of uniformity in responses of the three groups was found, with the first 10 subjects being college algebra, trigonometry, methods in high-school mathematics, solid geometry, educational psychology, supervised teaching, analytic geometry, general high-school methods, college geometry, and advanced college algebra. The most conspicuous disagreement was that heads of college mathematics ranked differential and

integral calculus eighth and ninth, whereas they ranked 22 and 23 on the basis of total replies. High-school mathematics teachers tended to favor professional courses to a greater extent than did college education department heads. It was concluded: "It would appear that the profession as a whole is closer to agreement as to what the professional needs are than is generally believed."

Slack (50) set up and evaluated a course pointed toward increasing competence of prospective teachers of secondary mathematics. A check-list of competencies for mathematics teachers was adapted from an authoritative list with the cooperation of practicing teachers. On the basis of that list experiences for a course were formulated, the course taught, and the attainment of competencies evaluated. Based on the outcomes from that course, recommendations for revision were made. It was concluded that six term hours would be required to attain the desired ends, a study of relative importance of the different competencies was needed, and more concrete experiences in demonstrating methods and technics and exploration of multisensory aids in teaching mathematics were needed. Suggestions for improving evaluation technics for such a course included substituting small groups for individual conferences, refinements of observational data, and improved testing.

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CHAPTER VI

J. FRED WEAVER

Teacher Education in Arithmetic

THREE years ago Burnett and Gragg (1) deplored the paucity of research in the broad area of "Teacher Education in Science and Mathematics" for the three-year period covered by their review. A similar concern, in regard to "Teacher Education in Arithmetic," can be noted for the three-year period just ending. Altho there has been some encouraging research activity, the amount completed and reported has been small in relation to the great need for productive research in this area.

Current Status of Requirements for Teachers of Arithmetic

Grossnickle (5), Layton (6, 7), and Rhoads (10) conducted independent studies which relate, in whole or part, to the academic and professional requirements for the preparation of teachers of arithmetic. Grossnickle's chief sources of data included general professional literature on the subject, catalogs from liberal arts colleges and universities which have departments or colleges of education that prepare teachers for the elementary school, and replies from a questionnaire sent to accredited teachers colleges. Layton's data were drawn from official certification rules and regulations for teachers of mathematics, Grades I thru XII, for each of the states and the District of Columbia; and from replies to questionnaires submitted to each state certification officer and to nationally recognized specialists in mathematics. Rhoads secured her data from normal school and teachers college catalogs; from letters of inquiry sent to the superintendent of schools, or public instruction, in each state and the District of Columbia; and from previous research and general professional literature on the subject.

All three studies pointed to the extremely low requirements in the subjectmatter of mathematics for those preparing to teach in the elementary schools. Both Grossnickle (5) and Rhoads (10) reported that three-fourths of the teachers colleges require *no* credits in secondary-school mathematics for admission. Furthermore, Layton (7) reported that only 10 states require any work in background mathematics at the college level for certifying applicants without teaching experience. The mean requirements were reported as .52 semester hours. Paralleling this condition, Grossnickle (5) reported that only one out of 62 departments of education in liberal arts colleges, and only three out of 18 colleges of education, require any work in background mathematics as part of the training program for elementary-school teachers. The mean requirements were reported as .1 semester hours for the departments of education and .5 semester hours for the colleges of education. The condition in the state teachers colleges is slightly better, but not encouragingly so. Between one-third and two-thirds of the state teachers

colleges require work in background mathematics, depending upon the different general or specialized curriculums offered. The mean requirements ranged between 1.2 semester hours and 2.0 semester hours. Generally speaking, both Grossnickle (5) and Rhoads (10) found that during the past 25 years, whereas the over-all training period for teachers in the elementary school has increased from a mode of two years to a mode of four years, the amount of required work in background mathematics has decreased dangerously. Both Grossnickle (5) and Layton (7) recommend six semester hours of work in background mathematics as a minimum requirement for elementary-school teachers, regardless of curriculum level of specialization.

As reported by these three studies, the situation as regards required work in the methods of teaching arithmetic is little better than that for required work in background mathematics. Again, the requirements are dangerously low. Both Grossnickle (5) and Rhoads (10) reported a marked tendency for work pertaining to the teaching of arithmetic to be absorbed as part of general methods courses. Grossnickle (5) reacted against this condition and recommended a separate course, apart from the one in general methods, dealing with the specific problems of teaching arithmetic in the elementary school. This was recommended as required work for all persons in training except those who will specialize in fields such as music and the arts.

For those who will teach arithmetic in Grades VII and VIII, both Grossnickle (5) and Layton (7) recommended the equivalent of a minor in background mathematics and a special course in methods of teaching mathematics at this level of the educational ladder.

Further Recommendations Which Point to Needed Research

Several significant articles and papers have appeared in recent professional literature which do not report completed research, but which do make suggestions and recommendations that may be significant in pointing the direction and trend of needed research in the future.

Mayor (8) forwarded six goals for the preservice and inservice training of teachers of arithmetic and discussed means by which these goals may be realized. Wren (13) analyzed functional competence in arithmetic into six attributes which were forwarded as major objectives in the teaching of arithmetic, and discussed the implications of each for teacher education. Altho these two sets of goals or objectives differ understandably in several respects, both Mayor (8) and Wren (13) find common ground in their recognition of the importance of "meanings" in the teaching-learning situation. Yorke (14) made recommendations for the preservice preparation of teachers, "based on the functional theory of education that the arithmetic taught and the processes stressed must be those most used in life." It should be noted that Wren's "functional competence" is allied very closely with the "meaning theory" of arithmetic instruction, but Yorke's "functional theory of education" is related very

closely to the "social-utility theory" of arithmetic instruction. These two points of view regarding the teaching of arithmetic are not identical.

Newsom (9) recommended that all prospective elementary-school teachers should have completed a minimum of two years of secondary-school mathematics for admission to teacher-training institutions; and that three, and preferably six, semester hours of work in background mathematics be required at the college level, in addition to a required course in the teaching of arithmetic. These are quite consistent with previously mentioned recommendations, such as those by Grossnickle (5). Newsom (9), furthermore, outlined in some detail the nature and content of the recommended work in background mathematics. Weaver (11) emphasized the importance of work in background mathematics at the college level. He, as well as Grossnickle (5) and Newsom (9), stressed the importance of emphasizing meanings and understandings in the background course if arithmetic is to be taught "meaningfully" in our elementary schools in the future. Wilburn and Wingo (12), in discussing the broad issues of an inservice training program, also recognized the need for directing greater attention to an *understanding* of arithmetic on the part of prospective teachers in teacher-training institutions, and the relation of this emphasis upon understanding to successful methods of teaching.

Almost without exception these articles and papers have brought to the foreground the crucial importance of basic mathematical understandings for the prospective teacher of arithmetic in the elementary schools. The research in this aspect of teacher-training is almost nonexistent, but the need for research activity is most urgent.

The Trend and Nature of Needed Future Research

Glennon (3, 4) was the only worker to report significant research on basic mathematical understandings in teacher-education programs. Based on a study of 144 freshmen, 172 seniors, and 160 teachers-in-service with experience ranging from one thru 34 years, all of whom were enrolled in one or another of three teachers colleges, Glennon (4) concluded that there is no significant difference in the achievement of basic mathematical understandings between: (a) teachers college freshmen and teachers college seniors: (b) teachers college seniors who have taken a course in the "Psychology and Teaching of Arithmetic" and those who have not taken such a course; and (c) teachers-in-service who have done graduate work in the "Psychology and Teaching of Arithmetic" and those who have not done such work. Also, virtual zero-correlation was observed between achievement of basic mathematical understandings on the part of teachers-in-service and the length of teaching experience.

Based on his own research findings, Glennon (4) reached conclusions which were thoroly consistent with the recommendations of other persons: that present preservice and inservice training programs are inadequate

from the standpoint of their attention to the development of basic mathematical understandings; and that adequate training programs must include, among other things, required work in background mathematics as well as required work in the specific problems of teaching arithmetic.

Fehr (2) listed the following as one of several problems "needful of solution and adaptable to action research" in the field of elementary-school arithmetic: "What educational preparation is both necessary and sufficient for the successful teacher of the newer arithmetic program?" More specifically, one might ask: In the preservice and in-service preparation of teachers of arithmetic, *what* work in background mathematics and related teaching methods is most valid and effective? A start has been made. Research, however, must lead the way in determining the validity and effectiveness of those and other hypotheses.

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